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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656]

Competition by roads, waterways and airways.

(Continued) (*).

Information regarding the year 1936.

Greece, Algeria, French Indo-China, Kenya and Uganda.

GREECE.

The *Official Journal* of the 30th December, 1936, published the text of the law « on the operation of suburban road services with mechanical traction ».

The essential clauses of this law are given hereafter.

Definitions.

Such traffic is to be considered as suburban road traffic as takes place over national, departmental, and municipal roads, and is worked by mechanical means, between two places more than 20 km. (12.4 miles) apart in the case of motorbuses and 50 km. (31 miles) in the case of lorries.

Methods of operation.

All suburban services for the transport of passengers, merchandise, and in general for any transport of any kind comes under the control of the State, whose task it is to investigate and organise all road traffic.

The existing services are carried out according to the three methods of operation A, B and C defined below, so that the complete control of these services will gradually come under the State.

(A) Operation by the State itself.

(B) Concession of the operation to a third party by agreement, for 5 years at the most.

In the case of competitive road services between places linked up by the railway, the concession is granted in preference to the railways, which can either operate the road service themselves or hand over the concession to a third party.

(1) See *Bulletin of the Railway Congress Association* starting with the June 1934 issue.

In this latter case, the State can introduce suitable means of transport belonging to the State over these roads.

(C) Over part of the road system, operation by private undertakings, without a concession, when so authorised.

The State can impose a tax in the case of any agreement for operation by a third party.

The State regulates the rates and itineraries by means of general ordinances which give the maximum and minimum limits. The concession holders of road services under each of the above three headings, as well as railway administrations, draw up detailed rates and routes within the limits laid down.

The concession holder can in no case hand over his rights to a third party unless the concession-holder is a railway administration which, on its own responsibility, can be replaced by a third party if authorized thereto by the Minister.

Each road carrier has to keep accounts of its tickets, goods and the mileage covered by each vehicle.

In the case of class (A) services, the Government can authorise the Hellenic State Railways to operate them on its behalf.

Owners of mechanical means of transport in operation before the publication of the present law will be compensated if their services are discontinued as a result of this law.

Private vehicles.

The circulation of vehicles of all kinds for private business is not allowed over licensed routes except under certain conditions.

Vehicles owned by the State, Municipalities, the Diplomatic Corps, doctors, journalists, and foreign tourists, as well as home vehicles touring the country are free to circulate on all Greek roads.

Lorry traffic.

In the case of routes licensed under headings (A) and (B), lorries can be worked freely within 50 km. (31 miles) of headquarters. For distances above 50 km. (31 miles) the concession-holder of the road service in question is to be paid a royalty fixed by the Minister.

Owners of lorries in circulation before the law on licensed routes must notify the State, within one month from the date of publication of the law, of the headquarters from which they will have the right to work within a radius of 50 km. (31 miles) as specified.

The dimensions of a loaded lorry must not exceed 2.50 m. (8' 2 1/2") in width and 3.20 m. (10' 6") in height from road level; the total maximum weight of loaded vehicles must not exceed 10 tons. The headquarters, or place of departure, the useful load and tare weight must be shown on the sides of the lorry.

Lorries are weighed on weighbridges which are located where laid down by each town and served by State employees.

* * *

Other clauses deal with the transport of mails, the staff (that actually employed on licensed routes passes into the service of the concession-holder), control and sanctions.

* * *

ALGERIA.

Algerian Railways.

(Joint Management of the Algerian State Railways and the P.L.M., Algerian lines).

A passenger transport plan drawn up conform with the decree on co-ordina- n was put into force on the 1st March, 36, on the eastern motor services of the giers Department. This plan cut down e motor services by about 50 %, and some cases increased the fares to bring em into line with the railway rates.

Subsequently, the enforcement of co- dination of passenger transport in the ree Algerian Departments resulted in marked reduction in the number of ad services, and the fares were in- eased at the same time.

In the course of the year 1936 the Co- dination Committee continued to ra- nalise transport and in particular dealt th the question of extending the new m to passenger transport on demand axi services). New regulations, intend- to end the competition of such servi- s with the regular services, when they ceed their proper functions, are being awn up.

FRENCH INDO-CHINA.

The Government General of Indo-Chi- has supplied the following informa- n about competition met with by the lway, chiefly from road services.

1. *Policing of road traffic.*

The only effective measure, the intro- ction of special police for the roads, s not yet been taken. In its absence, roads are badly policed, and the pu- transport services can evade their igations (restrictions regarding the ed, load, number of passengers, main- ance of vehicles).

The drivers of vehicles used for trans- t in common, however, have to under- regular medical inspection (every five rs).

In addition, a decree of the Governor General lays down that all public car- riers must be insured against accidents to their passengers and against third- party risks. The guarantee must be at least 500 piastres (5 000 fr.) per seat pro- vided, and 10 000 piastres (100 000 fr.) per vehicle in addition. The insurance firms must be approved by the Govern- ment. The application of compulsary insurance dates from the 1st January 1937.

2. *Co-ordination of transport* (Special regulations on transport in common).

The decree of the 6th May, 1933, and the ordinance of the Governor General dated the 28th November, 1933, by which transport in common in Indo-China is regulated, have now been put into force after some tentative efforts, the opposi- tion of the road carriers which the authorities at first tried to meet half- way at one time having been overcome.

A decree of the 25th March, 1935, de- fining the procedure for the authorisa- tion of public transport services, is now in force. Carriers had to regularise their services by obtaining authority to work them. The authorisation deeds imposed definite obligations as to the number of trips, timetables, rates, capacity of the vehicles, etc... though in practice such obligations are not much more complied with than the highway code. The Com- mittees on transport co-ordination, which meet periodically in each country of the Indo-Chinese Union are unanimously in favour of a special road police, which alone would make it possible to effecti- vely control the traffic and the effi- ciency of transport co-ordination.

The transport services in competition with the railway must also pay royalties. The payments are made regularly with- out difficulty in Tonking, Annam and

Cambodge. In Cochin-China they at first led to some slight disturbances, which are now settled, owing to certain mistakes made in applying the regulations on transport co-ordination.

The enforcement of royalties has not decreased the number of undertakings; new firms take the place of those giving up, and though the number of services in competition with the railway has decreased, the non-competitive or feeder services which do not have to pay royalties has increased. This was just one of the results desired. For example, in the Tonking the number of trips made daily by public transport vehicles in competition with the railway has fallen from 463 in 1934 to 334 in 1936, whereas the number of trips over non-competitive routes has increased from 315 to 488 in the same period. These figures are a definite proof of the efficacy of the steps taken; another proof is the improvement in the railway receipts, which will be balanced this year (1936).

3. *Improvement in railway operation.*

The railway has made further applications of the policy which consists in improving continuously the quality of the service offered, whilst keeping the rates very low.

For example, 4th-class vehicles have been progressively fitted with electric lighting, and equipped with seats in the middle; very comfortable new 1st and 2nd-class coaches and new restaurant cars have been put into service. The vehicles shortly to be built in France will be air-conditioned.

The railway has just taken delivery of some railcars to be used on the outer suburban lines, over which the traffic is very heavy, round Hanoi and Saigon. They will be put into service shortly.

The rates have not been increased since 1934. For the sake of clearness, some of the fixed rates have been discontinued and replaced by zone rates which give more or less the same results. The 4th-class kilometric rate in Indo-China is still the lowest in the world : the average receipt per passenger-kilometre in the 4th class is 0.0048.

On the 1st October last, the Trans-Indo-China Railway was opened to operation from end to end, i. e. over 1 729 km. (1 074 miles). The comfort of the journey has been much improved and the time will be appreciably reduced when the new locomotives ordered from France will be delivered. From now on, the run from Hanoi to Saigon takes 40 hours.

Finally mention must be made of an important re-organisation which, though its main object is to lessen the burden imposed on the budget of the Colony by the railway, will also improve the operating conditions by bringing the whole of the railway system of Indo-China under a single management, apart from the Hai-Fong to Hanoi and Yunnanfou line : this was the buying up by the Colony of the Phnom-Penh to Battambang and Mongkolborey line in Cambodge, and the Bendongxo to Locninh line in Cochin-China; the former has been operated by the Colony since the 1st January 1936 and the latter since the 1st July.

All these measures, as has already been stated, have improved the financial position of the railways. This result is all the more satisfactory as this year the railway has had to open long sections of new lines on which the receipts will only gradually reach the same level as on the other sections.

* * *

BRITISH COLONIES.

Kenya and Uganda.

A committee was appointed to investigate and consider the desirability of co-ordinating and regulating all forms of transport in the Kenya Colony.

This Committee has handed in its report to which is appended the text of a bill of law. We received a copy of this report by courtesy of the General Manager of the Kenya and Uganda Railways and Harbours. The following information is extracted therefrom.

The Committee are satisfied that unrestricted competition between all forms of transport is not in the best interests of the country, or even of the transport owners themselves, and are unanimously in favour of some form of co-ordination and regulation. The best way of attaining the desired end would be to introduce a system of licensing based on the acid test of public advantage and necessity.

To administer this system the Committee recommends the constitution of a Central Transport Development Board with power to appoint, if necessary, local agents or committees as required.

The text of the draft Bill includes clauses on compulsory insurance. The owners of all mechanically propelled vehicles used on a road should be compelled to insure themselves against third-party risks.

As regards ancillary transport (other than the business of a transporter for hire or reward) carried out by any person, the majority of the Committee, considering that this might reach proportions likely to prevent the desired result being achieved, propose that this also should be licensed, though the obligations imposed should be made as light as possible; other members consider it should be left quite unrestricted.

Differences of opinion also arose concerning the application of the regulations, certain members wishing to limit it to certain main scheduled roads, generally parallel to the railway, whereas the majority considered that the licensing scheme should apply to the whole Colony.

The Commission did not reject the idea of exclusive licenses, but only under certain conditions, particularly as regards the period for the existence of the licence and suitable conditions of operation and charges.

A temporary authorisation is provided for transport undertakings which have been carrying on the business of transport for at least a year, at the time the proposed Control Board commences operations.

Uneconomic roads should be given up in favour of improved roads with better alignment and conditions.

Finally without suggesting any modification of the existing laws as regards railways, the Committee suggest that no new railway line be built without seeking the opinion of the proposed Transport Development Board.

[625. 172 (.43)]

Permanent-way inspection car of the German State Railways,

by Dr.-Ing. MÜLLER, Reichsbahndirektor, Berlin.

A. — Foreword.

The *Bulletin of the International Railway Congress Association* for July 1936, p. 745, English edition, published a description of the Swiss Federal Railways' dynamometer car fitted with track inspection equipment. The same article also mentioned the *Hallade* equipment, the *Sperry* detector car, and the dynamometer car of the *Great Indian Peninsula Railway*, but made no reference to the *Deutsche Reichsbahn*'s permanent-way inspection car. The Reichsbahn owns

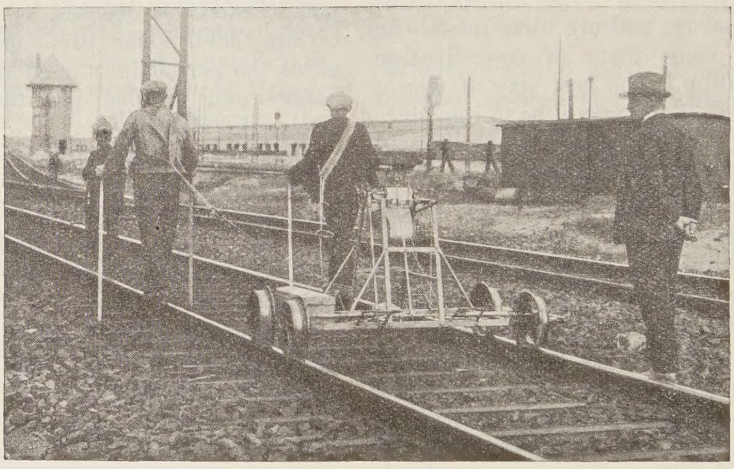


Fig. 1. — Dorpmüller track inspection appliance.

two permanent-way inspection cars, identical in principle, one of which has been in use about 8 years for inspecting all the main lines at regular intervals, 1 to 4 years. As these cars give very accurate results and have been a great success, their design and working will undoubtedly be of general interest.

B. — Conditions to be fulfilled by permanent-way inspection car.

As equipment on wheels for measuring the comparative level of the rails (super-elevation) and the gauge, the Reichsbahn used for scores of years the *Dorpmüller permanent-way inspection equipment*

(fig. 1). This is a sort of trolley which two men haul over the section to be checked. As a result the speed of operation and the work done per day are necessarily restricted. Consequently the equipment is not suitable for checking quickly long continuous sections, but is best adapted to checking short sections at intervals, as for example when passing work done to the track. Furthermore it is inadequate from the technical point of view, and no longer meets present-day requirements. It accurately measures the superelevation properly speaking, but, owing to its lightness, only gives the relative height of the two lines of rails in the *unloaded state*. Now, as regards smooth running of the vehicles and to appreciate the state of maintenance of a track, the level *under the wheel loads of the vehicles* alone matters. In addition, the Dorpmüller apparatus only measures the *superelevation* and the *gauge*, which two factors are not sufficient for forming a complete idea of the state of maintenance of the track.

When taking in hand the design of a permanent-way inspection car, the Reichsbahn laid down the following programme : The car must record *all* measurements required to show the condition of the track in plan and in alignment. Consequently it had to measure :

1. the *depression at the joints* of both lines of rail under vertical wheel loads of about 5 tons;

2. the reciprocal level of the two rails, also under about 5-ton vertical pressures;

3. the *curvature* of the track;

4. the *gauge*.

These measurements were to be recorded at a speed of about 60 km. (37.3 miles) an hour, in black ink on a large enough scale, on a paper band unrolling itself so as to give a continuous record which could be duplicated afterwards. The longitudinal slope of the track was not to be measured as the gradient section is of only secondary importance when considering the technical conditions of the track. As the vehicle was to be a simple *permanent-way* inspection car, no measurements in connection with the riding of the vehicles, such as, for example the movement of the bogies, the oscillations of the body, etc., were needed. On the other hand, special difficulties had to be overcome before it was possible to obtain measurements relating to the track, which were not made inaccurate by accidental oscillations of the vehicle, etc. This requirement was fully met, however, after some years of investigations.

C. — Measuring equipment.

1. *Scale of lengths.*

The recording band is 385 mm. (14 15/16" in.) wide. Its unrolling speed depends on the number of revolutions of the middle pair of wheels on one of the bogies and is so arranged that the curves are drawn to the scale of 1 in 5 000, so that 1 km. of track equals $\frac{100\,000}{5\,000} = 20$ cm. of the recording band.

Up to 1935, the unrolling speed was slower. The length was recorded to the inconvenient scale of 1 in 6 580, i. e. 1 km. of track equalled 15.2 cm. *Plate I* shows a record taken at this speed and *plate 2* one at 1 in 5 000 over the same section.

2. *Recording the track kilometrage.*

Along the top of the recording band (see plates 1 and 2), the lengths travelled

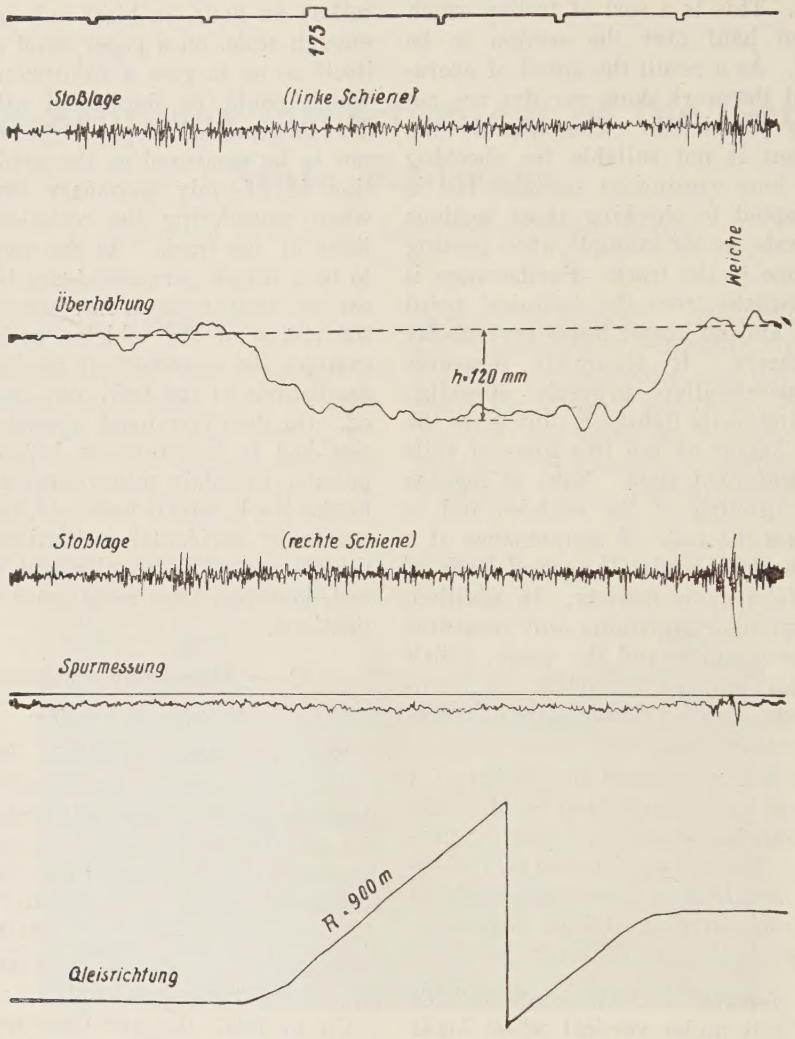


Plate I. — Part of a recording band (half size). — Year 1930. Scale 1 in 6580.

Explanation of German terms :

Stosslage = state of the joints. — Linke (rechte) Schiene = left (right) rail. — Weiche = points. — Spurmessung = gauge measurement. — Gleisrichtung = direction of the track. — Uberhöhung = superelevation.

by the car are recorded automatically by a pen which draws a line and also a small vertical line at each 200 m. At each kilometre a vertical line is drawn by the pen on the opposite side. When starting an inspection, the equipment is set to agree with a kilometre post of the line. The figures representing the kilo-

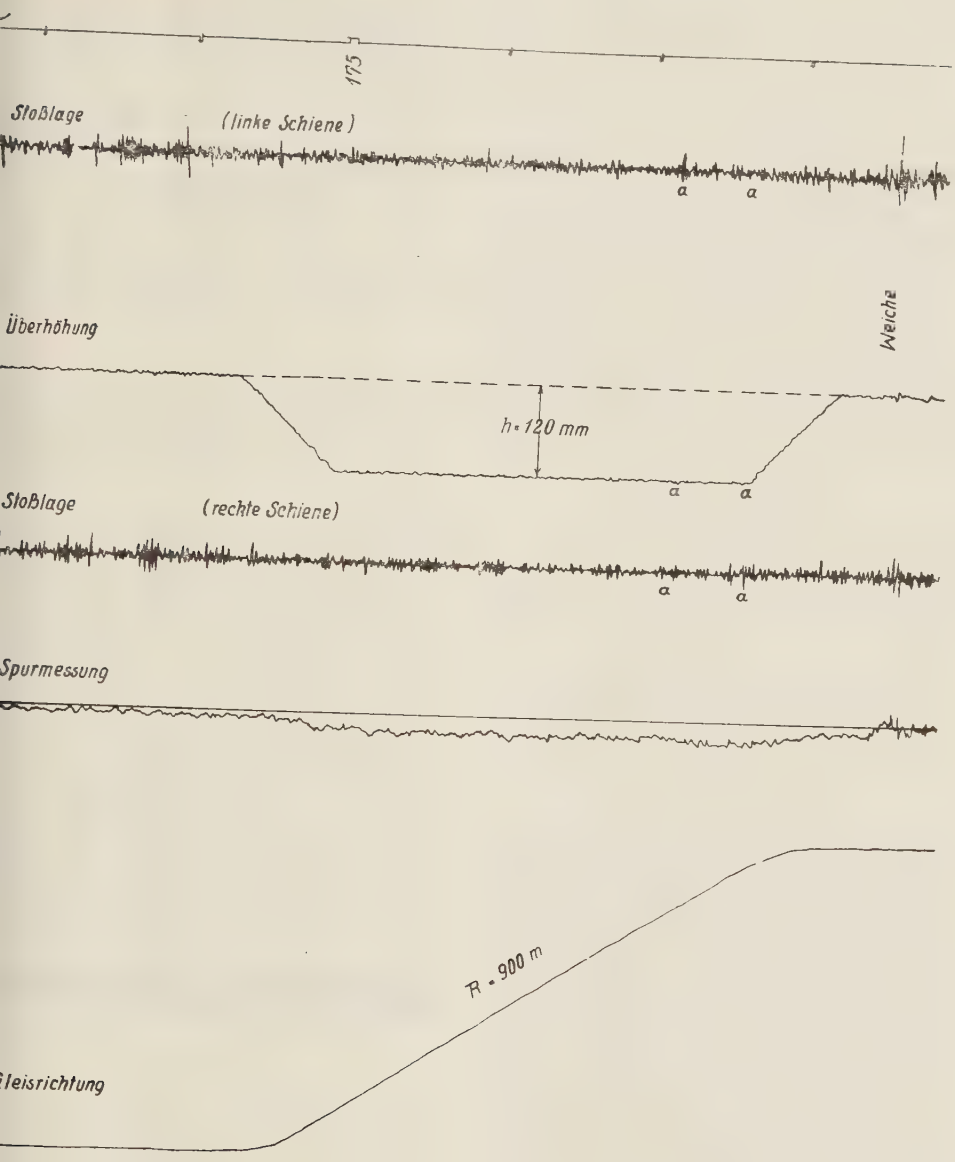


Plate 2. — Part of a recording band (half size). — Same section as *Plate I*, checked in 1936, after complete overhaul.

Scale of lengths : 1 in 5 000.

metres, names of stations, etc. are written in by hand whilst running.

3. *Measuring depressions at the joints.*

The depressions at the joints are most characteristic of the state of maintenance of a track. They are measured separately for each line of rails according to the principle of the measurement of the versines. For this reason a 6-wheeled bogie was used. The measuring chord on each side of the bogie consists of a special steel girder connecting the two outer axles. This girder is shown diagrammatically in figure 2 by the straight line AB. The

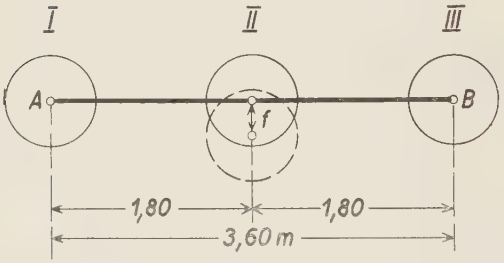


Fig. 2. — Measurement of the depressions at the joints under a six-wheeled bogie.

vertical movement of the middle wheel relatively to the centre line of the girder is transmitted by a cable provided with a recording pen. Consequently the versines f are measured for each rail in a vertical plane on a chord of 3.60 m. (11' 9 3/8") length (distance between centres of outer pairs of wheels). When passing over a low spot at a joint (fig. 3*a-c*) this method of measurement gives a curve like that shown in fig. 3*d*, and at the reduced scale of the inspection car, curves like those of figures 4 and 5 are obtained, the first of which shows a section with defective joints, and the other a section with joints in good condition. The recording band shows the line relatively to the left rail at the to above that relating to the right rail. Th depressions of the joints are shown fu size.

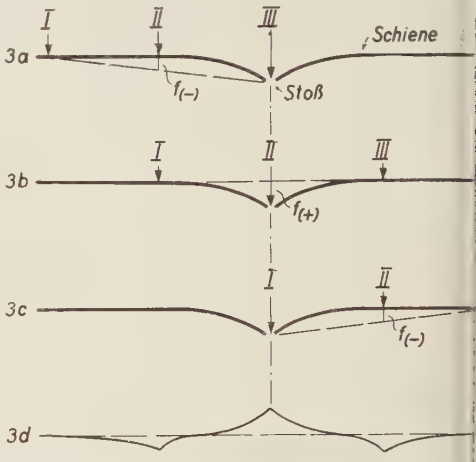


Fig. 3*a-d*. — Passage of the three pairs wheels of the bogie over a low joint a record of the measurement thereof (3*d*).

Note : Stoss = joint. — Schiene = rail.

Obviously these curves not only sho the depressions at the joints, but al make it possible to find defects in lev at other places, due for example to ce tain sleepers being insufficiently packe

The measurement of low joints cou still be completed by an automatic cou ter which would count up all movemen

Fig. 4. — Section with defective joints.

of the recording pen exceeding a sp cified amount, or the total distance tr

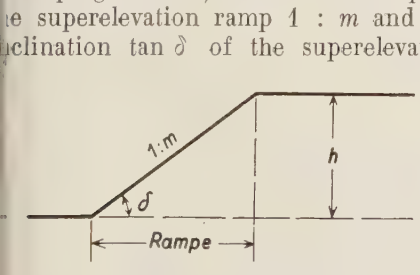
Fig. 5. — Section with joints in good condition.

Figures 4 and 5 are extracted from the actual recording band, full size.

elled by the pen could be counted by mechanical arrangement. Such additional devices supply data which enable n exact comparison to be made between he state of the joints on different sections of track of the same length. Tests ave been made with such fittings, but hey are not used in normal inspection vork unless specially required.

. Measurement of the reciprocal level of the rails.

In this operation, the question is to neasure the inclination of a vehicle axle elatively to a *horizontal reference plane.* This reference plane is given by two gyoscopes coupled together in a special vay. For dynamic reasons, a pendulum uch as that of the Dorpmüller instruent would be unsuitable on a vehicle aving to run at high speeds. The inclinaon of an axle relatively to the plane is ansmitted mechanically by cables to a ecording pen, so that the superelevations e drawn to a 1 in 5 scale on the measurg band. The diagram of superelevations recorded on the paper band between e two diagrams of joint depressions plates 1 and 2). The superelevation curve the same time gives a clear idea of the ate of the superelevation ramps (cant eveloping inclines). Between the slope of e superelevation ramp $1 : m$ and the clination $\tan \delta$ of the superelevation



g. 6. — Diagram of a superelevation ramp.

rve on the recording band (fig. 6), the le of lengths being 1 in 5 000, and the scale of superelevations 1 in 5, we get the equation :

$$1 : m = \frac{\tan \delta}{1\,000} \quad . \quad . \quad . \quad (1)$$

where $m = 1\,000 \times \text{cotan } \delta$ . . (1*a*).

If, for example, the slope on the recording band is $\tan \delta = 1$, the slope of the superelevation ramp is 1 in 1 000. By means of a suitable protractor drawn

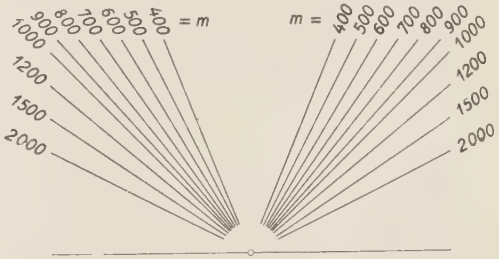


Fig. 7. — Protractor for measuring the incline of superelevation ramps.

on transparent paper (fig. 7) and applied on the superelevation curve, the slopes of the ramps can be read off directly.

5. *Checking the alignment of the track.*

The alignment of the track can be checked in two ways : by measuring in succession the *versines of the curves,* or the *angle* made at each instant of the run, by the longitudinal centre line of the vehicle with a fixed reference direction (for example North-South). In the first case, the *versines* are drawn as ordinates, which gives the diagram of *the versines,* or *the diagram of curvatures;* as a matter of fact, the curvatures $\frac{1}{R}$ of the track are proportional to the versines. In the second method, the angles of the curves passed over are noted on the diagram, which gives the *direction line* or *the angles diagram.* For checking the layout of the curves in the track, the di-

rection line is better than the diagram of curvatures, as the latter, even when the curves are well laid in, has a very irregular development and gives a slightly confused idea of the development of the curve, whereas the direction line is free from this drawback. It it true that the direction line could be deduced from the diagram of curvatures by means of an automatic integrator. It is preferable, however, to measure *directly* the alignment (the *route* of the inspection car). This explains why this latter process was chosen for the permanent-way inspection car.

At first, the fixed reference direction was established by means of a *navigation gyro-compass*. The movement of the inspection car relatively to this reference direction was transmitted *electrically* to the recording pen. The arrangement had several drawbacks, due mainly to the inertia of the transmission gear. The gyro-compass was therefore replaced recently by a specially designed gyroscope which resembles that used for measuring the superelevation.

In order to make sure that the true direction of the track is being measured, and not accidental oscillations of the vehicle, the body is so connected to the bogies that the play in the rotation about the vertical centre line is reduced to the permissible minimum.

The properties of the direction line (angles diagram) by the method used when pegging out curves is well known (1) :

on the *straight, a horizontal straight line* is drawn, i. e. from left to right on the diagram (see fig. 8);

on a *circular curve,* it is a straight line inclined to the horizontal (tan α) according as the curvature $\frac{1}{R}$ is more or less marked;

on a *transition curve* with lineally curvature it is a *second-degree parabola* .

When the vehicle takes a curve *to the right,* the direction line *descends* from left to right (example : fig. 8); when

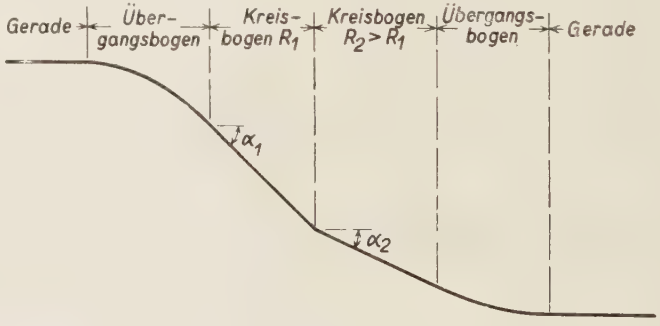


Fig. 8. — Direction line (diagram of angles) of a double depressed curve with transitions and straight sections at the ends.

Explanation of German terms :
Gerade = straight. — Übergangsbogen = transition curve. — Kreisbogen = circular curve.

taking a curve *to the left* it *rises* (example : plates 1 and 2).

The scale is selected so that the pen traces an ordinate of 1 cm. when the car passes a 50° angle of the curve; in other words, between the ordinates y (in

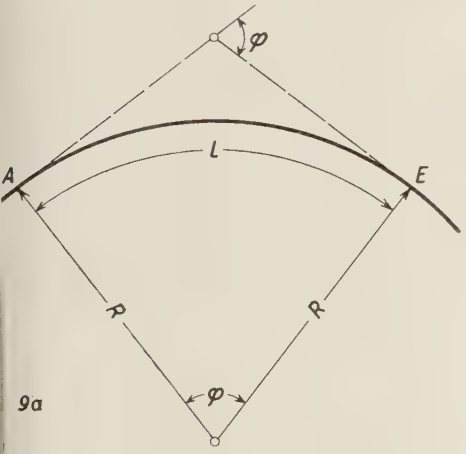
(1) *Bulletin of the Railway Congress*, February 1935, page 222 (English edition).

a.) on the paper and the corresponding gle in degrees, run over by the car, e equation is :

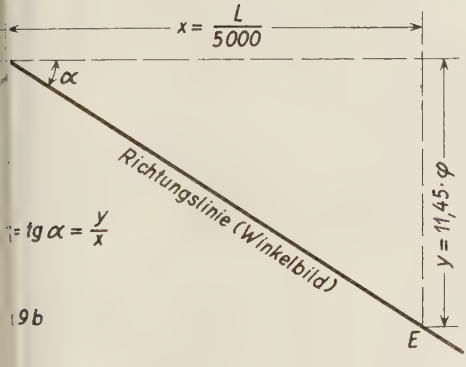
$$y_{(cm)} = \frac{\varphi^\circ}{5} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

hen φ is expressed in terms of the arc, is equation becomes

$$y_{(cm)} = \frac{180}{\pi} \cdot \frac{\varphi}{5} = 11.45\ \varphi \quad . \quad (2a)$$



9a



9b

. 9 *a-b*. — Relation between the radius of urvature R and the slope *y'* of the direction line.

Circular curve R.; *b*) direction line (diagram of angles).

ote : Richtungslinie (Winkelbild) = direction (diagram of the angles).

The relation between the radius of curve R and the inclination $\tan \alpha$ of the direction line can be deduced easily as follows :

The direction line EA corresponds in the diagram of the angles (fig. 9*a*) to the segment of arc AE (fig. 9*a*), of length L. In accordance with the scale of lengths 1 in 5 000, the length of arc L is represented as a horizontal abscissa of length

$$x = \frac{L}{5\,000} \quad . \quad . \quad . \quad . \quad (3)$$

(x and L in cm.).

The direction line has a slope to the horizontal of

$$y' = \tan \alpha = \frac{y}{x}.$$

Substituting for y and x the values given by equations 2*a* and 3, we get :

$$y' = \tan \alpha = \frac{11.45\,\varphi}{L : 5\,000} = 57\,300 \cdot \frac{\varphi}{L}.$$

Now from figure 9*a* :

$$\frac{\varphi}{L} = \frac{1}{R}$$

whence

$$y' = \tan \alpha = \frac{57\,300}{R}.$$

R is here the radius of curve in cm.; when R is in metres, we have :

$$y' = \tan \alpha = \frac{573}{R} \quad . \quad . \quad . \quad (4)$$

wherein :

$$R = \frac{573}{y'}. \quad . \quad . \quad . \quad (4a)$$

In other words, the slope y' of the direction line to the horizontal is proportional to the curvature $\frac{1}{R}$, or the radius of cur-

vature R is inversely proportional to the slope y' of the direction line relatively to the horizontal. The steeper the direction line, the smaller the radius.

The direction line is *at the bottom* of the recording band (plates 1 and 2). In

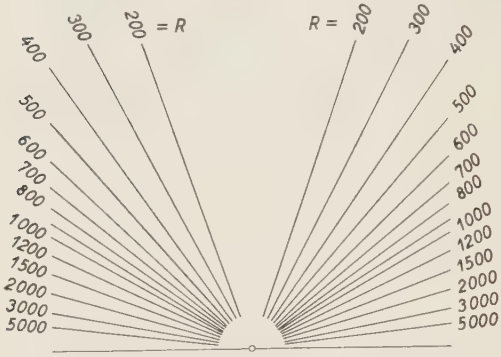


Fig. 10. — Protractor for measuring the radii of curvature R (in metres).

the same way as for the slope of the superelevation ramps, a transparent protractor (fig. 10) can be used to read off the radii directly.

6. *Checking the gauge.*

The gauge is measured by two *friction bars* about 1.30 m. (4' 3 13/64") long held against the inside edges of the rails by springs. The bars are fitted with special interchangeable heat treated steel shoes about 12 cm. (4 3/4") long which slide along the rails. Owing to wear, these shoes must be renewed after about every 5 000 km. (3 100 miles) of length has been measured. Long bars are necessary so as to pass over points and crossings (gaps at crossings and spring crossings).

The reciprocal horizontal movement of the friction bars is transmitted by a cable to a recording pen. A second pen draws a straight base line corresponding to the standard 1.435 m. (4' 8 1/2") gauge. The ordinates of the gauge curve referred to this base line consequently shows directly where the gauge is *slack* or *tight*. If the gauge curve falls *below* the base line, the gauge is *wide;* if above, it is tight. The transmission gear is adjusted to trace the gauge to the scale of 1 in 2. The gauge curve is located about the middle of the recording band (see *plates 1 and 2).*

7. *Measurement of the running speed.*

The inspection cars were also provided with apparatus for drawing a *speed curve* on the band. This was done away with later on, as being superfluous. As a matter of fact, the inspection cars work in such a way that the records are made *independently of the speed* and are not influenced by it. (See figs. 11*a* and 11*b*).

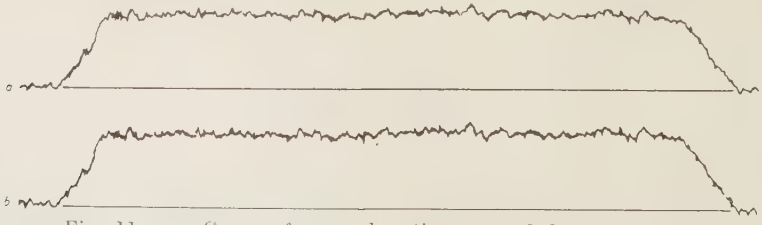


Fig. 11*a*. — Curve of superelevations recorded at the speed V = 60 km. (37.3 miles) an hour.

Fig. 11*b*. — Superelevations of the same curve, recorded at the speed V = 100 km. (62 miles) an hour.

There is no need, therefore, to record
e speeds during regular inspection
ps, as it is of no help in interpreting
e condition of the track and the speed
rve merely complicates the diagram.

— **Accuracy of the measurements.**

For the track inspection car to meet
e requirements of a measuring instru-
ent it must meet the following specifi-
ions :

1. The representation to scale of the
te of the track, given by the curves,
ust correspond to the actual condition
the track travelled over. The instru-
nts therefore must be accurately « ca-
rated ».

2. The measurements must not be af-
ted by accidental oscillations of the
hicle. In other words, if the same sec-
n of track is travelled over a number
times in succession the diagrams ob-
ned must agree.

3. The measurements must be inde-
ident of the speed of the car, as a
en speed cannot always be maintained
service. Consequently the records
st be the same for the same section of
ck, whatever the speed variations.

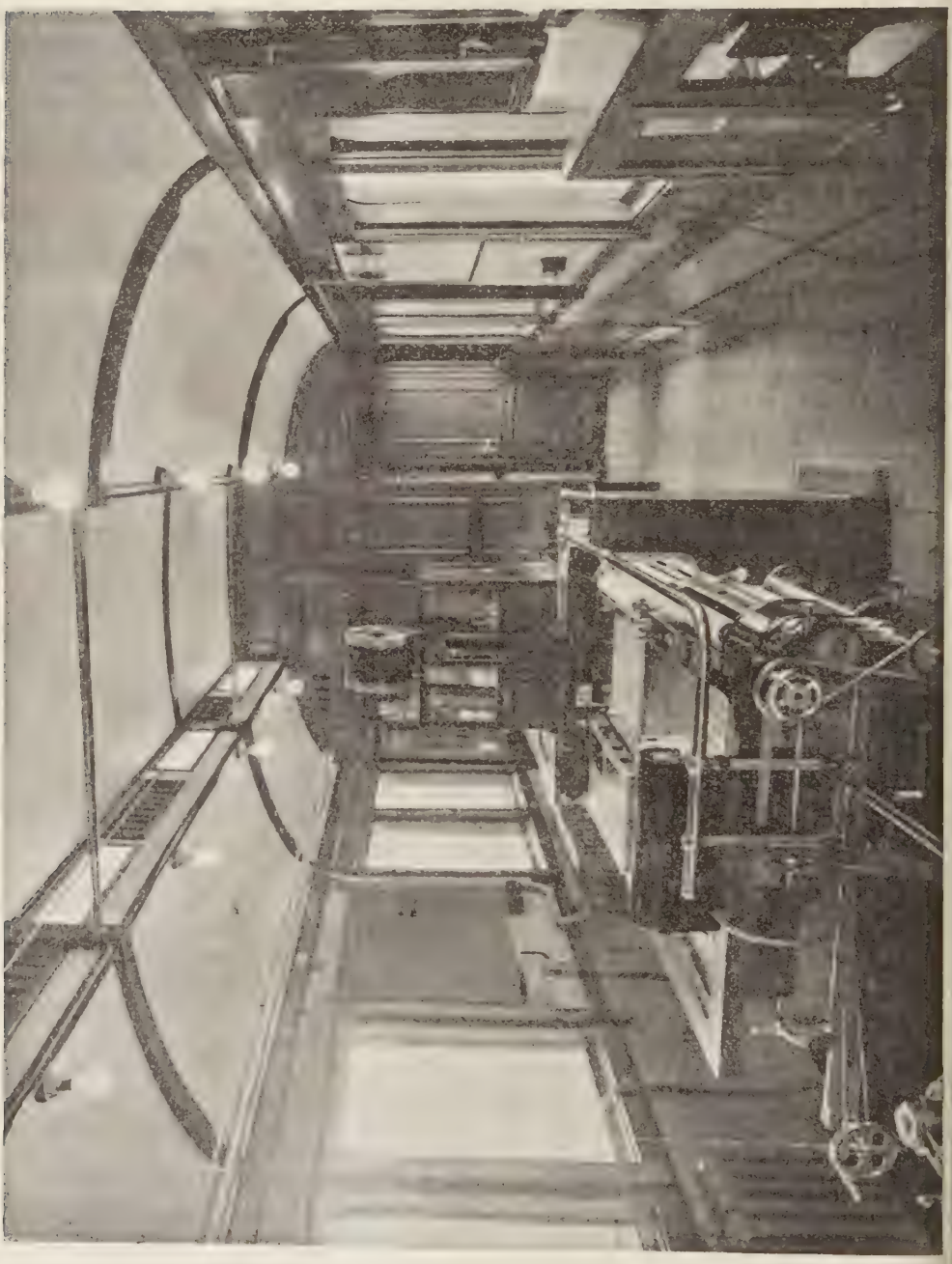
The two track inspection cars of the
chsbahn fully meet these conditions.
ure 11*a*, for instance, taken from a
ording band, shows the superelevation
ve recorded at 60 km. (37.3 miles) an
r, while figure 11*b* is a second check
the superelevation curve, but at 100
(62 miles) an hour. The perfect
ement between the two curves will be
d, as well as their independence of
speed.

The accuracy with which the low joints
the reciprocal levels of the two rails
recorded is shown, for instance, at
points marked *a* on the diagram, plate
2. In this case, the corresponding points on the two lines of rails show slightly different depressions, This small difference between the depression of the joints is shown at point *a* too, by the superelevation pen, to the corresponding scale, of course.

Many tests and regular inspection runs carried out over many years supply the proof that the accuracy of the records obtained on the bands with the inspection cars can hardly be bettered. The Reichsbahn has produced, in these inspection cars, a means of checking the permanent way which meets all requirements, i. e. a measuring instrument which records the actual state of the track independently of the speed of the vehicle or of the oscillations of the body inevitably set up, when running, by the various dynamic forces.

E. — Fitting out and use of the permanent way inspection cars.

The *electric current* for driving the gyroscope, lighting the car, etc. is supplied by a petrol engine with direct coupled generator. Each inspection car is coupled to a service vehicle. The inspection car consists of the instrument section, (fig. 12), a living room and a sleeping compartment for the engineer in charge, whilst the service vehicle contains sleeping accommodation for the staff, a workshop, the electric generating set and a kitchen. The *inspection train* consists of a locomotive, the service vehicle and the inspection car and is always run as a special train at 60 km. (37.3 miles) an hour. The inspection car is usually attached at the rear and is turned so that the track can be seen from the instrument section through the large window at the end of the vehicle.



he *staff of the inspection car* consists he engineer in charge of the inspec- run, a foreman and one or two fit-. In addition, the local permanent maintenance staff take part in the ular inspection runs.

he first permanent-way inspection was completed in 1929. It gave very d results, but as it could not cover whole of the main lines of the chsbahn a second car was built in- porating such modifications as expe- nce shewed to be necessary; it was ned out in the 1932 autumn.

hese two inspection cars have to ck the 77 000 km. (47 850 miles) (in nd figures) of track of the Reichs- n. The most important lines (those r which corridor trains and high- ed railcars operate) are inspected e a year, the other main lines and im- tant secondary lines every two years, l the less important secondary lines ry four years. In addition to the or- ary runs, special runs are made for ticular reasons, as for example when condition of the track has to be as- tained as quickly as possible with a v to increasing the speed, on a given .

he regular inspection runs are made ing the months of March to June, and gust to October. About 300 km. (186 es) of track are inspected daily. Up the end of 1936 the two inspection s had covered over 300 000 km. 6 000 miles) of track, so that each k had been inspected four times al- ly. In addition, over 30 000 km. 600 miles) of track on foreign rail- s had been inspected.

fter the records have been taken, the *dard* superelevations, gradients, etc. marked thereon. A number of copies then made and distributed to the area headquarters for the use of the operating and permanent-way departments.

The heads of the permanent-way sections find these diagrams most useful as they indicate just where the track requires attention and also whether work done has given the desired result. If the *recording band No. 1* be compared with *band No. 2*, the extent to which the inspection car has raised the education of the staff and improved the quality of the maintenance work is seen immediately. *Plate 1* is a record from newly laid, 1929 pattern track. The condition of the joints is not altogether satisfactory for new track; the alignment also reveals some irregularities, especially at the transition curves. As regards the relative level of the rails, this can only be described as very bad. Obviously too little importance was attached to the exact measurement of the superelevation. *Plate 2* shows the same track section completely overhauled and inspected in 1936. The condition of the track is much improved, both at the joints and as regards alignment, but especially as regards the superelevation and the superelevation ramps. The reciprocal levels of the rails can be said to be beyond criticism, as they are correct to within 1 mm. (0.039"). When in this condition, the track provides very smooth riding, even at high speeds, and it will remain in good state much longer than when serious defects exist from the beginning.

Figure 13 shows the curve of superelevations and the direction line of two reverse curves without any intermediate straight length. The first is a left-hand curve of 550 m. (27 1/2 chains) radius, and the second is a double depressed curve of 550 and 900 m. (27 1/2 and 45

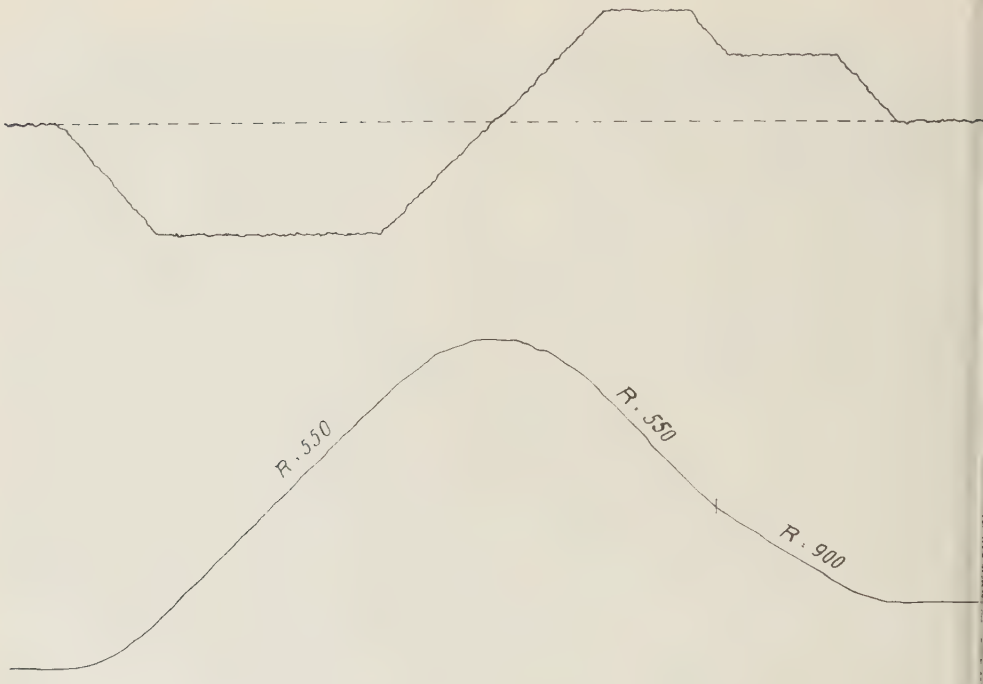


Fig. 13. — Curve of superelevations and direction line of two reverse curves without intermediate straight section.

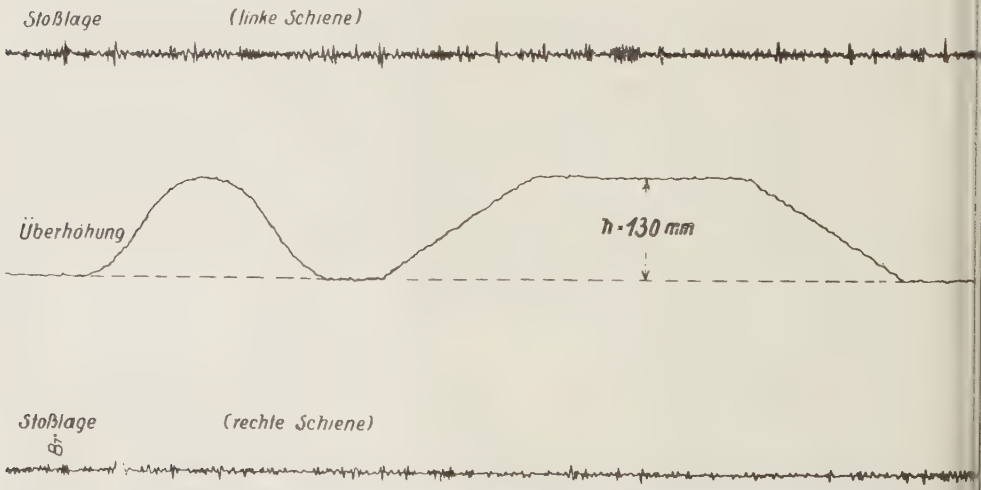


Fig. 14. — Condition of joints and superelevation curve of a curve with superelevation ramp of S form, and of a curve with straight superelevation ramps.

hains) radius. Figure 14 shows the ondition of the joints and the super-levation curve of two consecutive right-and curves on a section of line run over t speeds up to 160 km. (100 miles) an our. The first curve has superelevation amps of S form, the steepest slope being in 640 at the middle of the ramp; the second curve has straight ramps the steepest slope of which is 1 in 1 600.

The improvement in the state of the track during the last ten years, which has enabled the track to meet the requirements necessary for the present fast-train services (1), is largely due to the permanent-way inspection cars.

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(1) Further details on the construction of ne inspection cars are given in the following apers :

Dr. Zinsser and Herrmann : « Der Ober-aumesswagen der Deutschen Reichsbahn » The Reichsbahn permanent way-inspection ar), *Die Reichsbahn*, 1931, Nos. 20-21,

Herrmann : « Die Messung des gegenseitigen Höhenlage der Fahrschienen in den Oberbaumesswagen der Deutschen Reichsbahn » (Checking the relative levels of the rails by the Reichsbahn permanent-way inspection cars), *Organ für die Fortschritte des Eisenbahnwesens*, 1936, No. 15, p. 315.

[625.14]

Results of the Polish State Railways' experiments on the elastic deformations of the track and the stresses set up therein (*).

by Dr.-Ing. WASIUTYNSKI,

Vice President of the Technical Council, Polish Ministry of Communications.

One of the principal railway questions is the type of track best suited to the traffic. This question is closely bound up with the design and movement of the vehicles, and its solution depends on the relations between the vehicle and the track.

Briefly, the problem is to find a track equipment suitable for a given type of vehicle, which latter is being developed to meet the demands for increased loads and higher train speeds.

The importance of this problem is clearly shown by the programmes of the Sessions of the International Railway Congress Association, as it has been dealt with under one form or another at 7 Sessions out of thirteen.

At the Cairo Congress the question of the relation of the vehicles and track to suit modern conditions was gone into very fully. The construction and the motion of vehicles, the equipment and strength of the track were dealt with in the reports submitted by Drs. Matsunawa, S. Kurokochi and K. Asakura, Dr. Deyl and Messrs. H. Baumann and Jaehn as well as in the Special Report by Messrs. Desprets and Chantrell. The conclusions come to were :

« The computation of the strength o the railway track is especially an experi mental matter. Research work under taken by some Railways ought to b encouraged and followed with interest.

The position of these investigation was given in the above reports presented at the Congress.

Question I of the programme of th XIIIth Congress (Paris, 1937) dealt wit the « Construction of modern track fo heavy loads moving at high speeds an methods of modernising old lines fo such speeds and loads ». The detailed questionnaire showed that the main ob ject was to obtain particulars of th experience acquired to date in connec tion with the track, the modern loco motive and rolling stock being the re sult of former investigations. It appear difficult, however, to deal with the im provements introduced in permanent wa design without giving the data on which they are based.

For this reason, we thought the atten tion of the Congress should be draw to the experimental work done on th Polish State Railways during recen years. These tests were carried out t compare the effects on the track o

(*) Complement to the report by Mr. Lemaire, on Question I (Paris Session, 1937) : « The construction of modern track to carry heavy loads at high speeds, and methods of modernising old track for such loads and speeds. Facing points which can be taken at high speeds » published in the February 1937 number of the *Bulletin of the Railway Congress*.

ertain modern locomotives for work-ng heavy passenger trains at high peeds, such as the 4-6-0, 2-8-2 and -8-2 engines. Improved photographic ıethods now used to record the dis-lacement of selected points of the track ıake it possible to measure the elastic eformations and the stresses at these oints with great accuracy, whilst avoid-ng some defects of other methods.

The organisation of these tests and ıe results obtained were described in etail in a recently published book (*). he following conclusions were come to:

I. Effects of the moving loads on the rail supports.

. *Bearing coefficient of the sleepers under running trains and under hydraulic pressure.*

This coefficient expresses the relation etween the pressure p of the lower face f the sleeper on the ballast, and the epression y of the sleeper, i.e. :

$$C = \frac{p \text{ kgr./cm}^2}{y \text{ cm.}}$$

When investigating first of all the ffects produced by the load on the rail ıpports, the bearing coefficient of the eepers was found from the elastic de-ression of the whole of the sleepers of length of track, as well as of indivi-ıally loaded sleepers.

The observations showed that the aring coefficient of the sleepers, cal-ılated for the amount a group of eepers were depressed simultaneously ıder a running train, is about half that the bearing coefficient of a single sleeper under hydraulic pressure. For example, with broken stone ballast 35 cm. (14 inches) deep under the sleepers, the bearing coefficient of the sleepers under a running train taking their compression into account was 3 to 3.5 kgr./cm³ (96 to 102 lb. per cu. inch) whereas a single sleeper under hydraulic pressure showed a value of 5 to 7.6 kgr./cm³ (160 to 244 lb. per cu. inch). This result, when checked by the theory of elasticity, shows that the second of these values, ignoring the effect of adjacent sleepers on the elasticity of the sleeper taken separately, cannot be taken as the basis when calculating the deformation of the rail and the stresses in it.

No difference in the value of the bearing coefficient was found up to speeds of 107 km. (66.5 miles) an hour.

2. *Roadbed coefficient.*

The roadbed coefficient in the above case of a sandy formation was on the average 3.1 kgr./cm³ (100 lb. per cu. inch.), which made it possible to obtain the value of the coefficient of the broken stone ballast, i.e. the bearing coefficient of the sleepers in the case of an *absolutely rigid* formation.

3. *Ballast coefficient.*

The value of the ballast coefficient for broken stone was 6.1 kgr./cm³ (197 lb. per cu. inch.) which is the greatest value of the bearing coefficient of the sleepers, and proves that the much higher values of this coefficient, frequently used in calculating the track, are not justified.

II. Elastic deformations and stresses in the rail under vertical loads.

1. *Bases of the calculation of the rail under stationary loads.*

The calculation of the deformations and stresses in the rail under a single load or under a series of stationary loads shows that the differences in the de-

(*) « Recherches expérimentales sur les ormations élastiques et le travail de la su-structure des Chemins de fer » (Experi-nts on the elastic deformation of the track d on the stresses set up therein), by Dr. A. ASIUTYNSKI. Extracts from the *Annales de cadémie des Sciences Techniques*, Warsaw; l. IV. Paris 1937. Dunod, Publisher.

formations under the two methods of laying — rail considered as a girder resting on separate elastic supports or as a girder on continuous supports — does not exceed 1/2 %. The difference in the stresses in the rail does not exceed 5 %, the continuous elastic support hypothesis giving the lowest stresses.

This finding is very important as it considerably simplifies the calculation of the deformations and stresses in the rail under stationary loads, to be used for comparison with the deformations and stresses under the dynamic load of the trains. The above-mentioned difference of less than 5 % under stationary loads, the rail being taken as supported continuously, can be accepted, especially so as it gives a certain margin of safety in the dynamic effect of a load as calculated from its static effect.

2. *Effect of the speed.*

The effect of the speed of the progressive motion of the load measured from the average depression of the rail is insignificant as a rule. At speeds of 80 to 110 km. (50 to 68 miles) an hour, the average depression did not exceed 7 to 14 % of that under static loads. In the same way the average stresses measured in the rail at speeds up to 110 km. (68 miles) an hour were close to those under stationary loads.

2. *Effects of the design of the locomotives and the state of their tyres on the wheel pressures.*

The maximum depression of the rail under the locomotive driving wheels differs from that under stationary loads by a maximum of 28 %. The amount is greater at speeds of 80 to 110 km. (50 to 68 miles) an hour than at lower speeds. These differences depend on the design and state of repair of the locomotives and in particular on :

(a) The pressure of the cross heads on the slide bars, which reduces the load on the first pair of coupled wheels by up to 23 % of the load when stationary an consequently increases the load on th driven pair of wheels and the trailin coupled wheels.

(*b*) the periodic variations of th pressure of the coupled wheels owin to the inertia effects of the excess cou terbalance weight, and the alternatin masses.

(*c*) the periodical variations of th pressure of the carrying wheels an coupled wheels, due to tyre flats.

(*d*) the free oscillations of the wheel owing to the variation in their pressur given under *(a)*, *(b)* and *(c)*.

(*e*) the oscillations of the springs, du to the variations in pressure of th wheels and the depression of the rail.

The calculation of the influence these causes on the pressure of the ra gave results agreeing with those obtain from the observed depression of the ra

The whole of the above observatio leads to the conclusion that, when c culating the vertical depression of t rail under locomotives at high spee on level straight track, the following i creases in static wheel pressure shou be allowed :

At 80 to 110 km. (50 to 68 miles) hour, 30 %,

Under 80 km. (50 miles) an ho about 20 %,

the excess counterbalance weight a tyre flats being supposed to be reaso able.

4. *Conditions to be fulfilled in orc to limit the wheel pressure.*

To limit the dynamic pressure of t wheels, it is desirable that :

(*a*) the weight of the locomotive distributed over all pairs of wheels, t average extra load on the driven p of wheels and the trailing coup wheels being taken into account;

(*b*) the excess counterbalance weight e less than 10 % and be equally distri- ıted over the coupled wheels;

(*c*) the tyre flats be limited, not only regards depth, but also as regards aximum length, which is the greater ıe more pronounced the flat.

5. *Vibrations of the rails.*

The free vibrations of the rail during ıe movements of the trains have a eriod of 0.006" to 0.004". The ampli- ıde does not exceed 1 % of the depres- on of the rail under the wheel load.

6. *Retardation of the vertical deformation of the rail.*

The vertical deformation of the rail ccurs about 0.008" after the wheel caus- ıg it has passed.

7. *Maximum stresses.*

As a rule the stresses found in the rail nder each driving wheel considered eparately differ from the static stresses ore widely at 80 to 110 km. (50 to 3 miles) an hour than at lower speeds. In many instances high stresses in the ıil are not accompanied by a corres- ɔnding depression of the rail and fre- ıently the depression is less than the ılculated value under static load.

At speeds of 80 to 110 km. an hour the resses observed in the rail under each heel taken separately exceed by 45 %, ıd at lower speeds by 35 %, those cor- sponding to the widest observed va- ıations in depression.

Lateral forces and torsional forces.

The differences between the effect of e vertical wheel pressure depressing e rails and the corresponding stress ow that the stresses in the rails de- nd not only on the vertical forces but also on others such as the lateral and torsional forces. These differences make it possible to get an idea of the whole of the forces on a straight level line.

III. Longitudinal elasticity of the track.

1. *Longitudinal movements of the rails.*

The longitudinal forces acting on the rail through the adhesion of the locomotive driving wheels set up along the centre line of the track an elastic reaction of the rails and their supports. It follows that the variations in the tractive effort set up longitudal oscillations in the rails and sleepers.

The longitudinal oscillations of a rail with a period corresponding to that of the variations of the steam pressure in the cylinder near the rail appear to indicate that the cylinder on the other side of the locomotive has no marked effect on these oscillations.

2. *Longitudinal bearing coefficient.*

The value of the longitudinal bearing coefficient of the sleepers corresponding to a single rail, observed to be equal to 12.5 t./cm. (31 Engl. tons per inch.) approaches the value of the vertical bearing coefficient of the sleepers.

3. *Reaction of the rail.*

The reactions of the rails in the running road against the longitudinal forces approach those of a girder on an infinite number of elastic supports.

4. *Stresses in the rails.*

The stresses in the rails due to the forces acting at a tangent to the tread of the driving wheel tyres do not exceed 10 kgr./cm² per metr. ton (144.5 lb. per square inch per Engl. ton) of the axial load.

656. 222.1]

Note on Train Speeds,

by Lionel WIENER,
Professor at the University of Brussels.

PART II *(Continued)* [1]

Train speeds and services in different countries.

XX. — GERMANY *(concluded)*.

CHAPTER LVII.

The speeds.

LVII-1. — **Evolution.** — In railway story certain dates mark the beginning a radical change or the start of a new

The introduction, on the 15th May 33, of the first ultra-fast diesel train, « Flying Hamburger », has a double im to be considered as such a date. was the result and the practical solu- n of various problems concerning the rease in train speeds; it also introduc- new operating methods which could applied not only to railcars but also other kinds of traction.

The « Flying Hamburger » brought out things : first that it was possible to ntain very high speeds in regular y services, which was a considerable antage in dealing with air and road petition; secondly that excellent re- s would accrue from the running of light fast trains which would not only bring traffic back to the railways, but also assist in developing it.

Apart from technical improvements to the track, if very-high speed trains were to be run between existing ones, it became necessary to accelerate most of the latter, both passenger and goods, which led to a radical change in operating methods.

This is the reason the 15th May, 1933, is so important a date for every country, and especially for Germany. It marked the beginning of a general acceleration and improvement in its railway services, which has since been carried out systematically with the painstaking thoroughness that is one of her national characteristics. Each year has shown some improvement over the preceding year, and when once the initial step had been taken Germany continued to make remarkable progress, so that not only has she caught up arrears but even out-paced

1) Cf. *Bulletin of the Railway Congress*, October and November 1933; January, May, ne and July 1934; February, March, April, May, July and October 1935; March, May, ne, July and August 1936; February and August 1937.

TABLE 326.

GERMAN TRAIN SPEEDS IN 1897.

ADMINISTRATION.	RUN.	Distance.		Time spent.	Number of stops.	Speed.	
		Km.	Miles.			Km./h.	M.p.h.
Prussia.	Berlin-Hamburg. . . .	286	177.7	3 h. 36	0	79.4	49.3
Do.	Berlin-Halle	162	100.7	2 h. 08	0	76.0	47.2
Do.	Berlin-Magdeburg . . .	142	88.2	1 h. 58	2	72.2	44 9
Do.	Berlin-Cologne	576	357.9	9 h. 21	29	61.6	38.3
Saxony.	Leipz.-Dresden-Neustadt.	115	71.5	1 h. 46	1	65.0	40 4
Mecklemburg.	Neustrelitz-Warnemünde	132	82.0	2 h. 31	16	52.5	32.6
Bavaria.	Munich-Ulm	146	90.7	2 h. 10	2	67.4	41.9
Wurtemberg.	Stuttgart-Immendingen .	147	91 3	2 h. 57	10	50.4	31.3
Baden.	Basle-Mannheim . . .	258	160.3	3 h. 36	10	72.0	44.7
Do.	Basle-Heidelberg . . .	251	156 0	4 h. 05	25	61.4	38.2
Alsace-Lorraine.	Weissenburg-Basle. . .	208	129.3	3 h. 13	9	64.6	40.1

other countries slower to follow in her wake. This progress can be traced to a series of stages, each beginning with speed tests after which the authorised maximum speed was increased.

TRAIN SPEEDS IN 1897. — Maximum authorised speed was 80 km. (50 miles) an hour, or by special permission, 90 km. (56 miles). At the time, the Berlin-Hamburg line already headed the list with 70 km. (43.5 miles) an hour or 81 (50.3 miles) deducting stops; all the trains of the other Administrations were slower.

France and England only, boasted average speeds exceeding 80 km. (50 miles) an hour.

THE 1901 AND 1902 BERLIN-ZOSSEN MILITARY LINE TESTS. — In order to ascertain latent speed possibilities and the best way to improve them, a series of tests were started in 1901. They were more in the nature of preliminary tests concerning existing coach designs and track construction, so as to adapt them to speeds up to 200 km. (125 miles) an hour. At the trials, a speed of 157 km. (97.6 miles) an hour only was reached but even so, the track originally built for speeds up to 80 km. (50 miles) an hour only, proved inadequate at the higher rates of speed.

Tests carried out in 1902 determined the tractive resistance of trains at different speeds up to 120 km. (75 miles) an hour.

TESTS ON THE HANOVER-SPANDAU LINE. — This section is 243.5 km. (151.3 miles) long, with curves of 1 000 to 3 766 m. (50 to 188 chains) radius and three curves of 750 m. (37 1/2 chains) only. The profile (1), which had no gradients stee-

(1) Although generally laid with 41 or 43.5 kgr. (82.6 or 87.7 lb. per yard) rails, there were still some sections with 33.4 kgr. (67.3 lb. per yard) rails.

Table 327.

HIGHEST OVERALL SPEEDS IN 1897.

Run.	Distance. Km.	Distance. Miles.	Time spent.	Speed Km./h.	Speed M.p.h.	Company or Administration.
London-Bristol	192	119 3	2.15	85.2	52.9	England, *Gt. Western Ry.*
Do. Exeter	...	...	...	86.0	53.4	Do. *Do.*
Do. Doncaster	251	156.0	3.00	83.7	52.0	Do. *Gt. Northern Ry.*
Do. Carlisle.	481	298.9	5.50	82.7	51.4	Do. *L. and North Western Ry.*
Do. York.	303	188.3	3.45	80.8	50.2	Do. *G. N. and N. Eastern Rys.*
Paris-Calais	295	183.3	3.30	84.3	52.4	France, *Nord,* « de luxe ».
	...	...	3.42	79.0	49.0	Do. *Do.* rapide.
Do. -Bordeaux.	585	363.5	8.00	73.1	45.4	Do. *State.*
Do. -Marseilles	863	536.3	11.50	72.9	45.3	Do. *P.L.M.,* « de luxe ».
Do. -Les Aubrais.	121	75.2	...	78.9	49.0	Do. *P.O.*
Do. -Havre.	228	141.7	3.30	65.1	40.5	Do. *Ouest.*
Brussels-Ostend.	120	74.6	1.35	77 8	48 3	Belgium, *State Rys.*
Do. -Arlon	199	123 7	3.08	63.6	39.5	...
Vienna-Budapest	278	172.7	4.05	68.1	42.3	Austria-Hungary (11 stops).
Alexandria-Cairo	209	129.9	3.20	62.7	39 .	*Egyptian State Rys.*
Venlo-Flushing.	209	129.9	3.40	57.0	35 4	*Netherlands State Rys. Co.*
Bologna-Brindisi	763	474.1	14.00	54.3	33.7	Italy, *Rete Adriatica.*
Rome-Milan	469	291.4	8.39	54.1	33.6	Do. *Rete Mediterraneo.*
Wirballen-Petrograd	892	554.3	16.55	52.7	32.7	Russia.
Malmoe-Stockholm.	618	384.0	12.40	48.8	30.3	Sweden.
Basle-Lucerne	94	58.4	1.55	49.0	30.4	*Central Swiss Ry. Co.*
Irun-Lisbon	1 077	669.2	24.05	43.3	26.9	*Norte* (Spain) and Portugal.
Lisbon-Oporto	343	213.1	10.48	32.0	19.9	*Portuguese Rys. Co.*
Moscow-Kansk	4 523	2810.5	240.00	19.0	11.8	Siberia.

er than 1 in 300 was an easy one. A andard 40-axle 318-tonne (313 Engl. ons) test train was used for speeds up 120 km. (75 miles) an hour and a ghter 20-axle 156-t. (153.4 Engl. tons) ain, up to 140 km. (87 miles) an hour. he line included several obligatory eed restrictions (1).

With 100 % braking power, a stop om a speed 130 km. (80.8 miles) an hour was made in 1 400 m. (1 530 yards), which was greater than the distance between the distant and home signals.

These tests showed that, from the traction point of view, much had still to be done. Two of the three locomotives tested, a 4-4-2 and a 4-4-0, were unsteady at a speed of 120 km. (75 miles) an hour, and none of the three was able, save when running light, to reach the required

(1) Between Berlin and Lehrte (40th km. = 25th mile) where the maximum speed llowed was reduced to 40 km. (25 miles) an hour, there were three speed restrictions o 90 km. (56 miles) and another at Hamerten when crossing the bridge over the Elbe, o 60 km. (37.3 miles).

speed of 140 km. (87 miles) an hour. With the heavier train, a speed of 93 km. (57.8 miles) an hour was reached and, with the lighter one, 103 km. (64 miles).

However disappointing these results may have been, they showed on what lines it would be necessary to improve the existing state of affairs as they pointed out the weakest points.

The average speed continued to increase slowly, partly because the railway system was split up among a number of independent administrations.

For a long time the record was held by the *Prussian State Rys.*, whose Hamburg and Wittenberge 159.2 km. (98.9 miles) were covered in 2 h. 31 m., i.e. at an average speed of 86.1 km. (53.5 miles) an hour (1).

1904 TESTS ON THE OFFENBURG-FREIBURG (BADEN STATE) LINE. — A new type of *Atlantic* covered this 62.8 km. (39.0 miles) section, on the 4th November 1904, in 32 1/2 minutes, i.e. at the average speed of 116 km. (72.1 miles) an hour. As a consequence, the maximum authorised speed was raised to 100 km (62 miles) an hour and the timings revised. The Dutch express was allowed 43 minutes to cover this section in ordinary service and when delayed (usually at the Basle customs), 40 minutes only. This entailed respective overall speeds of 88 and 96 km. (54.7 and 59.6 miles) an hour. In spite of this, the Berlin-Hamburg 6 daily expresses running at over 80 km. (50 miles) an hour average speed retained their interest (2). But it should be remembered that the Berlin-Hamburg, Berlin-Hanover and Berlin-Halle lines were ideal ones for high speed running.

Although the *Baden State Rys.* in turn speeded up their services, they could not vie with the Prussian expresses, as their Karlsruhe-Freiburg line, which climbed 103 (340') in 80 km. (50 miles), was a hard one. In spite of this, the timings of the Milan St. Gothard and Berlin express and of the 12 daily fast and 13

TABLE 328.

BEST GERMAN TRAIN SPEEDS IN 1905.

Administration.	Run.	Distance.		Time spent.	Speed	
		Km.	Miles.		Km./h.	M.p.h.
Baden State.	Karlsruhe-Freiburg. . . .	135	83.9	1.36	84.1	52.3
Do.	Freiburg-Oos (Baden-Baden)	102.9	63.9	1.11	87.0	54.1
Do.	Offenburg-Karlsruhe . . .	72.2	44.9	0 54	80.2	49.8
Do.	Freiburg-Offenburg. . . .	62.8	39.2	0.43	87.6	54.4
Do.	Karlsruhe-Mannheim . . .	60.6	37.7	0.43	84.6	52.6
Do.	Freiburg-Lahr	45.0	28.0	0.32	84.4	52.4
Alsace-Lorr. Rys.	Strasbourg-Colmar. . . .	65.4	40.6	0.48	81.8	50.8
Saxon State Rys.	Leipzig-Riesa.	65.8	40.9	0.51	77.4	48.1

(1) Leaving Hamburg at 12.32 p.m.; arrival at Wittenberge at 2.23.

(2) The other fast runs were Hanover-Stendal, (Berlin) Angermunde-Stettin, also covered at more than 80 km. (50 miles) an hour, and Berlin-Röderau-Dresden-Neustadt.

ıburban trains, all of which were fre-uently duplicated during the summer eason, was notable.

The speed limit having been increased 105 km. (65.3 miles) an hour the *Ba-arian State Rys.* next took the lead when, from the 1st June 1911, the 198.7 km. 122.8 miles) of the Munich-Nuremberg ne, with its 200-m. (656') climb, were overed in 2 h. 15 m., i.e. at an average peed of 88.3 km. (54.9 miles) an hour, y train *D* 39, starting at 8.23 a.m. and s relief, whose weight reached as much 475 tonnes.

At the time, the French services were e faster. Although, owing to the weight the trains, the timings had been relax-l [1], the Paris-Calais run [2], includ-g a 4-minute stop at Abbeville (at the 76th km. = 109th mile) to take water, as accomplished in 1911 in 3 h. 21 m., e. at 89 km. (55.3 miles) an hour and e Paris-Abbeville section, at 94 km. 58.4 miles).

The « Nord Express » held the French cord, the 154 km. (95.7 miles) from aris to St. Quentin being covered in 1 h. m.; Express No. 197 (leaving at 7.35 m.) made the run in 1 h. 33 m., at an erage speed of 99.3 km. (61.7 miles) hour, which was the fastest run in ırope, the *North Eastern Ry.* running 99 km. (61.5 miles) an hour from ırlington to York, and the *Caledonian*, 98.1 km. (60.1 miles), from Forfar Perth.

PRESENT POSITION. — The 1926 track, laid with 49-kgr. (98.8 lb.) per yard rails, was suitable for speeds up to 200 km. (125 miles) an hour on the straight, but speed restrictions would have had to be done away with, curves flattened out, superelevation increased, the number of joints reduced and spaces between distant and home signals increased. A programme remedying these defects on 22 high-speed lines totalling 9 270 km. (5 760 miles) was drawn up and, since 1927, ten million Rm. annually earmarked for the purpose.

The points, which previously included curves of 190 m. (9 1/2 chains) radius, were replaced by others with 500-m. (25 chains) radius (or in exceptional cases 300-m. = 15 chains) whilst awaiting the minimum of 1 200 m. (60 chains) which is to be the rule for all curves. The new standard 30-m. (98' 5 1/8") rail was to be laid on 10 450 km. (6 493 miles) of track and, in order to increase the speed by 5 km. (3.1 miles) an hour, the following standards were adopted :

Minimum radius.	*Maximum speed.*
400 m. (20 chains)	100 km. (62 miles) p.h.
600 m. (30 chains)	120 km. (75 miles) p.h.
800 m. (40 chains)	140 km. (87 miles) p.h.
1 000 m. (50 chains)	160 km. (100 miles) p.h.
1 600 m. (80 chains)	200 km. (124 miles) p.h.

IN 1932, when the high-speed diesel rakes were put into service, the maximum speed was increased from 100 to 120 km. (62 to 75 miles) an hour, and to 110 km. (68.3 miles) for the *FD* trains when late. The extent to which these figures have been exceeded is a

(1) In 1904, it took 3 h. 1 m. to cover the 297.23 km. (184.7 miles) from Paris to alais. The Paris-Amiens section was covered at 101.6 km. (63.1 miles) an hour including service stop at Amiens, and the Amiens-Calais section at 96.06 km. (59.7 miles). This peed has not been equalled over the same route, since.

It was over this route and so as to do away with the service stops that the *Nord Ry.* rst investigated Ramsbottom watering troughs. The large tenders the locomotives have nce been provided with have enabled the Company to avoid the troughs altogether.

(2) Leaving at 9.50 a.m.

well-known fact, ever since the « Flying Hamburger » was put into service, in 1933.

In 1934, other tests were made, mainly in connection with the permanent way. They were carried out on the 57 km. (35.4 miles) Stendal-Salzwedel section of the Berlin-Bremen line, laid with 30-m. (98' 5 1/8") rails, some of which were welded to reduce the number of joints. Speeds of between 115 and 145 km. (71.5 and 90 miles) an hour were reached. So as to be able to stop trains safely whe running at 150 km. (93 miles) an hou the distant signals were spaced 1 200 in stead of 700 m. (1 312 instead of 76 yards) from the stop signals.

In spite of the stupendous work re quired for revising the timetables an nually, this has actually been done sinc 1930. The following table taken fro *Die Reichsbahn*, brings out the annu progress very clearly :

TABLE 329.

NUMBER OF RUNS MADE AND TRAIN-KM. (TRAIN-MILES) COVERED AT DIFFERENT SPEEDS.

Year.	At 100 km. (62 miles) p. h.			At 95 km. (59 miles) p. h.			At 90 km. (56 miles) p. h.		
	Number.	Train-km.	Train-miles.	Number.	Train-km.	Train-miles.	Number.	Train-km.	Train-miles.
1931	—	—	—	—	—	—	2	97	60.
1932	—	—	—	2	572	355.4	5	6 891	4 281.
1933	4	1 146	712.1	4	1 146	712.1	30	4 504	2 798.
1934	15	3 059	1 900.8	50	6 712	4 170.7	167	16 551	10 284.

LVII-2. — **Apportionment of various kinds of traction.** — Local economic conditions led the German Railways to electrify certain lines — whose present mileage is 1 948 km. (1 210 miles) — the main lines with 15 000-volt 16 2/3-cycle current, and the others with 800-volt. The latter comprise both suburban and mountainous district lines, where very high speed is unattainable.

On the other hand, the *Reichsbahn* has put into service a number of high-speed diesel rakes linking up Berlin with large provincial towns or interconnecting the latter. Fast steam trains run along the same routes but with a different object, so their timings are easier. No useful purpose would therefore be served comparing their speed with that of railcars, especially as it would really h been higher had no railcars been oper ed. We shall therefore only menti them when it is useful to do so.

The mileage of lines having ste trains, railcars or both kinds of exp ses, is given in table 330. The total trains mileage is not the summing up the amounts under the three headings, many trains are necessarily included der two of the headings.

(a) **Propeller propulsion** (fig. 409). The first tests of the vehicle built

Table 330.

LENGTH OF LINES SERVED BY HIGH-SPEED ELECTRIC OR STEAM TRAINS AND FAST RAILCARS (1936 summer services).

Company or Administration.	Electric or steam trains.		Railcars.		Both.		Total.	
	Km.	Miles.	Km.	Miles.	Km.	Miles.	Km.	Miles.
Germany.								
Reichsbahn	18 572	11 540.3	3 507	2 179.2	18 572 (1)	11 540.3 (1)	18 572	11 540.3
Lübeck-Büchen	75	46.6	—	—	75	46.6	75	46.6
Eutin-Lübeck	33	20.5	—	—	33	20.5	33	20.5
France.								
Nord	584	362 9	128	79.5	276	171.5	988	613.9
Est	951	590.9	65	40.4	546	339.3	1 566	973.1
Alsace-Lorraine	271	168.4	153	95.1	58	36.0	482	299.5
P.-L.-M.	3 027	1 880 9	—	—	1 102	684.8	4 129	2 565.7
P.-O.-Midi	3 375	2 097.1	430	267.2	310	192.6	4 115	2 557.0
Etat	1 127	700.3	367	228.1	2 696	1 675.3	4 190	2 603.6
Total	9 335	5 800.6	1 143	710.3	4 988	3 099.4	15 475	9 615.9
Italy.								
Rapidi	1 162	722.1	1 155	717.7	278	172.4	2 495	1 550.4
Belgium.								
Belg. Nat. Rys. Co.								
Block-trains (3)	(2)		(2)	(2)	975	605.9	1 464	907.7
International (3)	489	303.9	—	—	489	303.9		
Nord-Belge do.	111	69.0	—	—	111	69.0	111	69.0

(1) Electric or steam-locomotive-hauled expresses also run on all diesel-served German lines.

(2) On a certain number of lines, some of the block-trains are worked, to the same timings, by diesels or by steam locomotives.

(3) This figure only includes international lines, and not those having block-trains as well.

Steinitz and Pfeiffer were carried out on the *Reichsbahn* in 1919 and led to the foundation, in 1924, of the *Company to investigate Transport Technique*.

The points to be investigated comprised the braking apparatus first and, next, the best shape the vehicle should be built to. The *Reichsbahn*'s Leinhausen maintenance shops turned out a new vehicle, streamlined according to the *Krucken-*

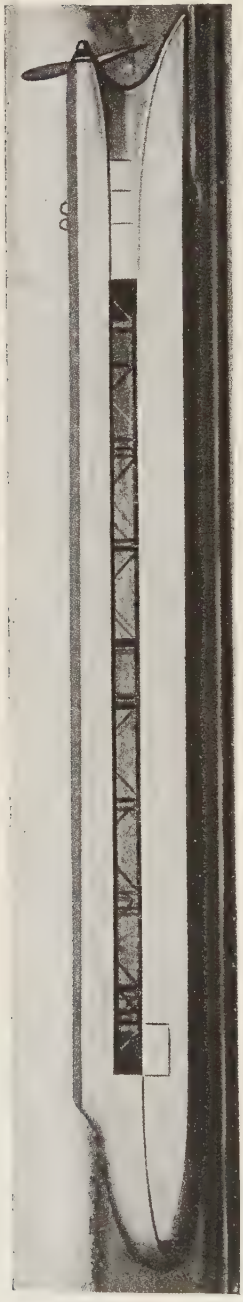

Fig. 409. — The Kruckenberg propeller-driven railcar.

berg and Stedefeld designs. This was tested on the Burgweld (near Hanover)-Celle line.

It had 40 to 50 ordinary or 12 Pullman seats (1). Owing to the car's fast acceleration, a speed of 100 km. (62 miles) an hour was reached in 66 seconds, and a distance of 985 m. (3 230') and a speed of 150 km. (93 miles), in 2 minutes. The highest speed reached during the tests, on the 21st June 1931, was 182 km. (113.1 miles) an hour, but this was not the maximum that could have been attained as the straight section of line was too short. The same car ran from Hamburg to Berlin in 1 h. 36 m. 2 s. i.e. at an average speed of 174 km. (108.1 miles) an hour, with a maximum of 230 km. (142.9 miles), the highest speed ever reached on any railway.

In calm weather, 200 H.P. was required to maintain a speed of 150 km. (93 miles) an hour, with a fuel consumption of 20 litres per 100 km. (7.1 Br. gall. per 100 miles).

But the success which attended the trials both of diesels and steam-hauled trains, switched interest into other channels and the propeller-driven vehicle was temporarily abandoned.

(b) **High-speed railcars and diesel rakes.** — Although the actual service speed of railcars was progressing, the introduction, on the 15th May 1933, of the « Fliegende Hamburger » was a great step forward. It introduced as practical propositions, both streamlining and the running of ultra-high speed twin-units (fig. 411). It also completely broke away from previous methods, both by the length of the non-stop run (the longest

(1) The vehicle was 26 m. (85' 3 5/8") long; its weight empty was 19 tons, and its wheelbase 20 m. (65' 7 3/8").

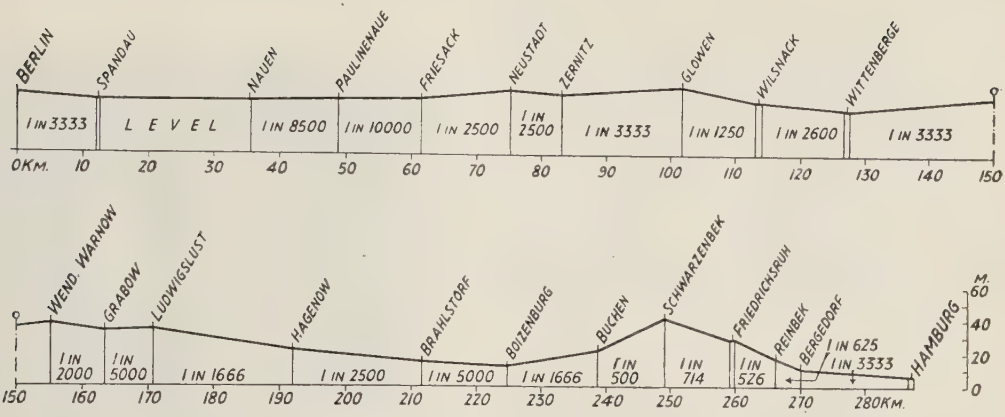

Fig. 410. — Gradient section of the Berlin-Hamburg line.

in Germany) and by its high overall speed. The Berlin-Hamburg was, it is true, particularly suitable for such speed (fig. 410); nevertheless, careful driving was necessary at both ends, the loss being made good by covering long distances at 155 km. (96.3 miles) an hour.

From the outset, the service was most successful and averaged 56 passengers per trip during the first six months. The set completed its thousandth journey on the 30th April 1935, having then carried over 100 000 passengers and worked 322 000 train-km. (200 000 miles). It had been in actual service 85 % of the time, overhauling or repairs accounting for the remaining 15 %.

On and from the 8th October 1934, the train was retimed, henceforward leaving Berlin at 11 instead of 8 a.m. Its place was taken, at the original departure time, by a new fast *FD* steam-hauled train.

Other countries, such as Belgium, soon put similar rakes into service (fig. 412).

The « Fliegende Hamburger », with its 125.7 km. (78.1 miles) an hour, held the world speed record for two years but on the 15th May 1935 it passed to the « Fliegende Kölner » [with 137.9 km. (85.7 miles) an hour from Hanover to Hamm] which still holds it. Since 1936, it has been followed by the *Atchison, Topeka and Santa Fe*'s, « Super Chief », which covers the 325.4 km. (202.4 miles) from la Junta to Dodge City in 2 h. 25 m., i.e. at an average speed of 134.7 km. (83.7 miles) an hour. This train, consisting of 7 to 9 carriages weighs 550 to 700 t. and is hauled by a double 3.800-h.p. diesel locomotive.

In the meantime, the German railways' permanent way and signalling were further improved and pneumatic, electro-magnetic and hydraulic brakes investigated so as to obtain satisfactory deceleration from a speed of 160 km. (100 miles) an hour. The « Fliegende Hamburger » 's Knorr compressed-air brake, which acts by means of shoes on the wheel centres, stops the rake, from this speed, in 1 200 m. (1 312 yards). The electro-magnetic brake was since evolved so as to reduce this distance to 850 m. (926 yards).

Thanks to their two 410-h.p. engines, the 13 new twin-units ordered from the *Görlitz Works* can reach this speed. In essentials, these rakes differ but little from their prototype, the main altera-

tions comprising the use of the Scharfenberg automatic coupling which allows of multiple control and improved streamlining, particularly in the lower part of the cars. These vehicles have also been lengthened by 2 m. (6' 6 3/4"), so as to provide 81 seats in each unit. The first of them were used for the « Fliegende Kölner » which was brought out on the 1st July 1935, and accomplishes, on its way, the fastest run in the World.

At the same period, triple units were ordered as well.

At a speed of 160 km. (100 miles) an hour the outer pairs of wheels take up to 3/4 of the total weight of the rake. Compared with steam locomotives, these vehicles have an appreciable advantage in that their centre of gravity is only 1.35 m. (4' 5 3/16") above rail level, while that of the locomotives is at a height of 2.15 m. (7' 5/8"). In France and Denmark, the stability of the stock has been increased by reducing by 50 % the conicity of the tyres, which is now 1 in 40 instead of 1 in 20.

Though the introduction of the twin diesels was an important step in the right direction, these rakes had a serious drawback as compared with steam-hauled trains which allowed, when traffic demanded it, of an easy increase in the number of available seats. For this reason, any steps taken to remedy this drawback, however secondary they might appear to be, are of importance.

The capacity of the German diesel twin units is 102 seats, whereas that of an articulated steam train, such as the « Silver Jubilee » consisting of 7 coaches (including a restaurant car) is nearly 200, and that of a *P.L.M.* three-coach train (plus a restaurant car), 228 seats.

First of all, diesel triplets were evolved. This increased the number of seats

without any drastic changes; later, multiple unit rakes were brought into use.

On the 15th May 1936, new services including an extended Berlin-Cologne train serving most important Westphalian towns, were introduced; they were worked with diesel rakes made up of two twin units. The two sets were severed at Hamm, one of them proceeding via Essen and Düsseldorf, the other via the shorter Wuppertal route to Cologne.

On the up journey, one of the twin-units is attached to the Cologne-Hamburg rake, as far as Hamm, where the Cologne-Düsseldorf rake joins it, and whence the two Cologne sections run solid to Berlin.

Incidentally, it should be noted that the distance from Berlin to Hamm is about the same as that from London to Newcastle, and that whereas the German run of 441 km. (274 miles) was made in 3 h. 17 m., including a stop at Hanover, the 432 km. (268.3 miles) of the English run took 4 h. 20 m. including a stop at Darlington.

Since the 15th May 1936, the Cologne-Hamburg diesel service has been diverted from the Cologne-Wanne-Eickel-Münster route to the Düsseldorf Hamm one, being attached as far as Hamm as a multiple unit to the « Fliegende Kölner ». This increases the distance by 22.2 km. (13.8 miles) and 12 minutes. On the return trip, it follows the « Fliegende Kölner » at a 5-minute interval;

The South of Germany diesel rake comprises two sections which separate at Nuremburg, one of them running to Munich and the other to Stuttgart, the latter portion saving 67 minutes on the best previous timings.

Coupled multiple units have also been used in Holland, triple-diesel sets working between Utrecht, Eindhoven, etc. As the streamlining of the tail end was not

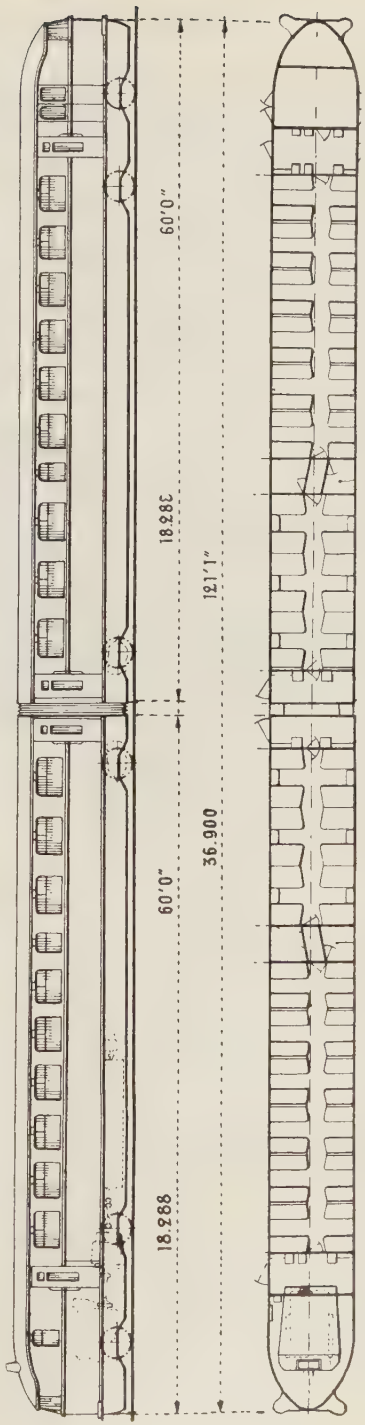

Fig. 312. — Twin diesel railcar of the *Belgian National Railways Company*.

designed for this purpose, this causes some change in their aerodynamics but this is of no great importance at these trains' relatively low speed.

Longer diesel rakes are run in the U.S.A. The « City of Portland » consists of six coaches, including sleeping-cars, restaurant-cars and tourist coaches, and a new nine-coach train has followed. The *Union Pacific* runs permanently coupled sets, each unit of which can be uncoupled for repairs. As on the *French Nord*, the triplets of the *Gulf, Mobile & Northern* consist of three non-articulated coaches, so that if need be, any of them could be replaced by a spare one.

Accelerated passenger train services as opposed to fast ones were introduced in Germany as from May 1935 in the Ruhr, Rhine and Main districts, as well as in Saxony and East Prussia.

(c) **Electric traction.** — As in the case of steam traction, the present practice is the result of a series of speed tests stretching over a long period.

THE HEILMANN LOCOMOTIVE. — The first tests took place on the former *Chemin de fer de l'Ouest* (France) in 1894, with the 650-H.P. Heilmann locomotive « La Fusée Electrique », built by the *C^ie de Traction*. It reached a speed of 108 km. (67.1 miles) an hour between Paris and Rouen. The *C^ie Cail* of Paris, then built two further locomotives; these were equipped with two eight-wheeled bogies and had double the power. The electrical equipment was in the fore, the generator in the rear part of the locomotives. They were tested at various speeds from 30 km. (18.6 miles) upwards, between Paris and Mantes. The weight of the 12-coach corridor-trains was 150 tonnes.

1901 TESTS ON THE BERLIN-MARIENFELDE-ZOSSEN MILITARY LINE. — This line was experimentally equipped with three-phase current for motor coaches specially built by Messrs. *Siemens & Halske* and the *A.E.G.* (fig. 413). Although they reached a speed of 120 km. (75 miles) an hour, and even a maximum of 160 km (100 miles), they chiefly showed that it was essential to improve both the permanent way and the rolling stock (1). The track was therefore relaid with 42-kgr./m (84.7 lb. per yard) rails and 32 kgr./m (64.5 lb. per yard) check rails (instead of the original 32-kgr. rails), the radius of curves increased to 2 000 m. (6 560') the signals spaced further apart giving a 2-km. (1.24 miles) braking distance and the rolling stock improved (2). A very odd means of investigating the collector's behaviour was introduced : the motor coach was hauled at 135 km. (8 miles) an hour... by a steam locomotive.

The trials were resumed in 1903, both with *A.E.G.* and *Siemens & Halske* motor coaches, and a speed of 210 km (130.5 miles) an hour attained.

At the same time, a *Siemens & Halske* locomotive reached 130 km. (80.8 miles). Finally, in 1903, the motor coaches reached 200 km. (125 miles) an hour, which it would seem hard to better. A two-bogie *Siemens* locomotive, which reached a speed of 130 km. (80.8 miles) an hour was also tested successfully. Although it was thus proved that it was possible to run fast electric trains, the scheme long remained in abeyance.

Single-phase current has since taken

(1) The track was laid with 32-kgr./m. (6 lb. per yard) rails; the axle load was 15 (14.7 Engl. tons).

(2) The six-wheeled bogie wheelbase was increased from 3.50 to 5 m. (11' 6" to 16' 5"

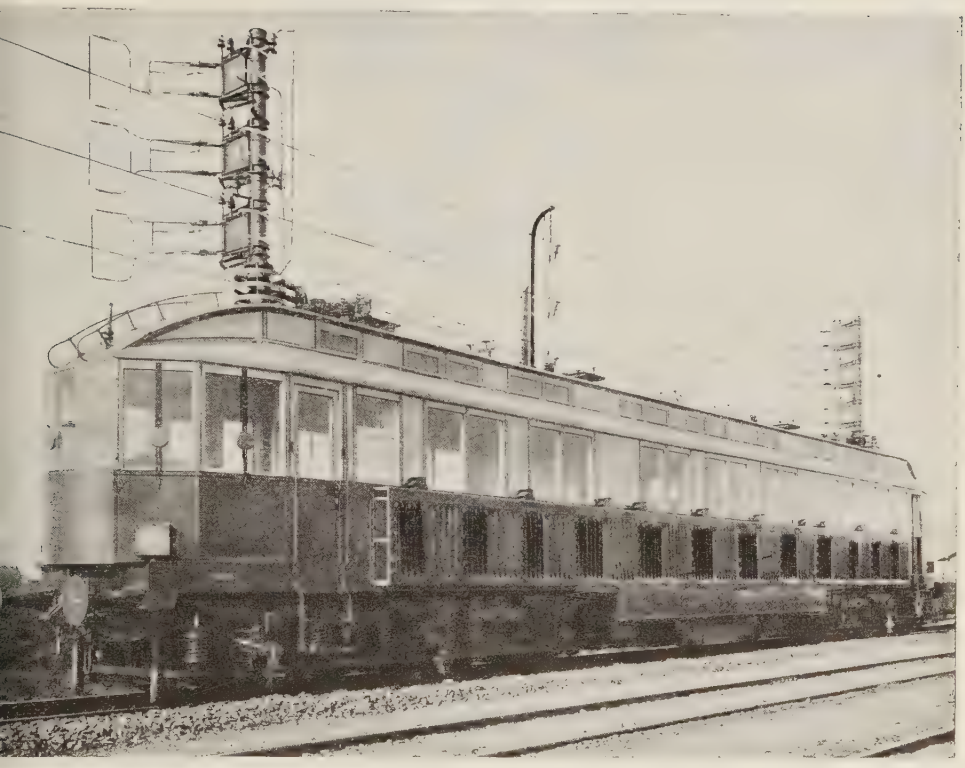

Fig. 413. — *Siemens & Halske* high-speed motor coach.

e place of three-phase and in 1911, a ecial train carrying members of the ichstag from Dessau to Bitterfeld, and uled by an electric locomotive, reached speed of 135 km. (84 miles) an hour. is speed is now, not only technically as 1911, but also economically possible. After the first electrified line was ened to traffic on the 15th June 1903 tween Berlin and Lichterfelde Ost, and first *State* line, between Berchtesga- n and Königsee on the 29th May 1910, electrification of suitable systems was ried out such as that of Dessau-Mag- burg (the oldest), the Silesian system and, largest of all, the Southern German (fig. 414). The Berlin, Hamburg and Basle (frontier) lines were also electrified. Save the latter, the Leipzig-Magdeburg, whose original section from Dessau to Bitterfeld was electrified in 1911, has the easiest gradients. On the other hand, the Silesian system only includes heavily graded lines :

Breslau-Görlitz	1 in 53
Niedersalzbrunn-Halbstadt	1 in 67
Ruhbank-Liebau	1 in 100
Lauban-Kohlfurt	1 in 167
Lauban-Marklissa	1 in 143
Hirschberg-Landshut	1 in 40
Hirschberg-Strickern	1 in 40

Fig. 414 (*). — Map of German electrified lines.
The Nuremberg-Augsburg line has been electrified since this map was drawn.

The Baden system, still in the embryonic stage, and the Bavaria-Wurtemberg are also located in hilly country. The latter includes the 6 km. (3.7 miles) 1 in 45 Geislingen bank (Augsburg-Stuttgart line) which is negociated at 67 km. (41.6 miles) an hour, the Freilassing-Berchtesgaden railway with its 5 km. (3.1 miles) of 1 in 25 gradients; the Munich-Garmisch-Partenkirchen line with 1 in 62 gradients, and 1 in 27 on branches. The system includes two important main lines, from Stuttgart to Munich-Salzburg, and from Munich to Nuremberg (towards Berlin); both are steep, and as the trains are heavy, the work required from the electric locomotives is arduous.

The 1-C*o*-1 (series E 04) locomotive were designed for reaching 130 km. (80.5 miles) an hour. As a matter of fact during the 1933 trials, they reached speed of 142 km. (88.2 miles) an hou with a 309-t. (304 Engl. tons) train More recently, between Munich and Nuremberg, train ***D*** 39 with 14 coache weighing 665 t. (654.5 Engl. tons) empt and nearly 700 t. (689 Engl. tons) i working order, hauled by a 1-D*o*-1 ele tric locomotive was able to easily main tain a speed of 110 km. (68.3 miles) a hour on long level stretches, a maximu speed of 142 km. (88.2 miles) an hou being reached. The electric locomotiv work the 221-km. (137.3 miles) Stuttgar

(*) From *The Railway Gazette*.

nich service non stop, this being the gest in Europe, except for the Italian te Railways' Florence-Rome and Pisa-me runs.

(d) **Electric motor coaches.** — Fast ctric motor coach services were intro-ced by the *Reichsbahn* at the same ne as the diesel rakes, on the 15th May 36. The Stuttgart-Ulm 193-km. (120 les) run is non-stop, thereafter pro-ceeding to Munich and Freilassing and climbing beyond the 19 km. (11.8 miles) 1 in 25 bank from Bad Reichenhall to Berchtesgaden.

The 72-seater third-class observation coaches built in 1935 by the *H. Fuchs Waggonfabrik Co.*, with glazed roofs (fig. 415), run on the Bavarian and Wurtemberg hilly lines. The current is collected by two pantographs and fed to two 240-H.P. motors carried on the bogie (1).

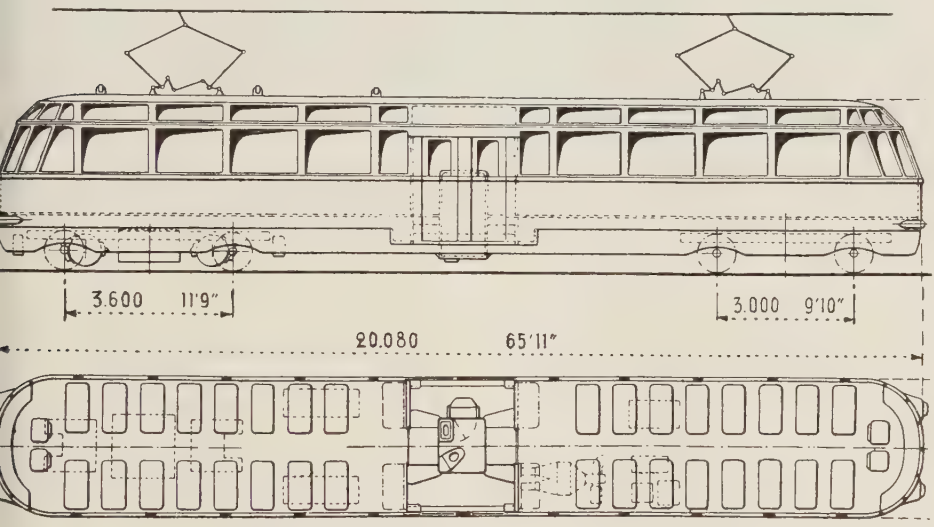

Fig. 415. — Glas-top electric motor coach.

(e) **Steam locomotive traction.** — am locomotive capacity for speed has n gone into more systematically in many than anywhere else. Besides the usual technical reasons, Germany has an extra incentive to do so : she has extensive coal mines and no oil fields, being in similar economic conditions, in

(1) The leading dimensions are :

heel diameter	0.950 m. (3' 3 1/8").
gie wheelbase	3.600 m. and 3.000 m. (11' 9 3/3" and 9' 10 1/8")
stance between bogie centres	13.815 m. (45' 4").
eral dimensions :	
length	20.080 m. (65' 9/16").
width	2.950 m. (9' 8 5/32").
height	3.800 m. (12' 5 5/8").
mber of seats	36 and 36.
re	49 t. (48.2 Engl. tons).
eight per seat	0.68 t. (0.67 Engl. ton).

this respect, to those of France and Belgium. As these investigations were conducted with an open mind, the data thus collected are valuable. Curiously enough, it was in connection with the « Fliegende Hamburger » that attention was called to the steam locomotive's latent possibilities as, when the diesel rake was out of commission, a light three-coach train (one more than the diesel), hauled by a steam locomotive, originally built for a maximum speed of 120 km. (75 miles) an hour now covered long distances at 140 km. (87 miles) with a maximum speed of 153 km. (95 miles). It is truly remarkable that old locomotives should thus have equalled, to within 12 minutes, the « Fliegende Hamburger »'s spectacular performance. ,

This led to the designing of new locomotives which included streamlining among their features, thus reverting to a practice started many years previously, and whose efficacy had been demonstrated by their diesel competitors.

STREAMLINING. — The oldest tests, rudimentary though they were, seem to have been undertaken in England, in the forties, by the *Great Western Ry.*'s inspired engineer, Brunel, but they led to nothing.

The first to apply streamlining on a large scale was the French *P.L.M.*, in *1894*, which fitted « wind cutters » to

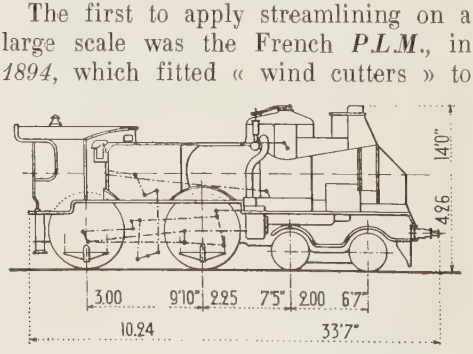

Fig. 416. — *P.L.M.* « wind cutter » locomotive.

the smoke box, domes, and front of the cab, of a number of 4-4-0 locomotives and, later, to other classes as well (fig. 416).

The next step was an application of streamlining made by Frederik Upham Adams in 1900, at his own expense, to a complete *Baltimore & Ohio R.R.* train (1), comprising a locomotive and five coaches, which he caused to be cased in to within a few inches of the rails, from the tender to the tail where it finished off in a point. All lateral projection were eliminated. So that even the windows should cause no wind resistance they were fixed and ventilation obtained by suitable air equipment. The length of the couplings was reduced to a minimum and the bellows made as short and flat as possible. This trial train ran from Washington to Baltimore in 37 minutes. Unfortunately, an ordinary non-streamlined train (the « Royal Blue ») made the same run on the same day in 37 1/2 minutes, so the invention was given up in 1901 : it had come before its time. It is doubly remarkable that this should actually have happened as long ago 37 years ago and that all memory of such a fact should have been so entirely obliterated.

Soon afterwards, however, the idea once again crossed the Atlantic and landed in Germany. In 1904, Messrs. *Henschel & Son*, under the direction of Dr von Wittfeld, fitted the front end of a 4-4-4 locomotive and its tender with a streamlined casing (fig. 417), this wheel arrangement then being used for the first time. Another notable feature consisted in locating the cab over the leading bogie which was brought further

(1) The work was carried out at the Mount Clare Shops and cost $ 8 000.

Fig. 417. — Old cased-in locomotive, built by Messrs. *Henschel*, Kassel.

'ward for the purpose, so that the low-essure cylinders had to be fitted be-nd the bogie instead of between the es. In 1912 the locomotive had its ing and front cab removed (1) g. 418).

These locomotives were intended to ıl rakes of 5 bogie vehicles weighing) t. (177 Engl. tons) at a maximum ed of 130 km. (80.8 miles) an hour. During the trials on the 23 km. (14.3 miles) of the Marienfelde-Zossen line they hauled six coaches weighing 224 t. (219.4 Engl. tons) at a speed of 125 km. (77.7 miles) an hour and on an ordinary line at 118 km. (73.3 miles). 110 km. an hour (68.3 miles) was reached in 10 minutes 30 seconds and the 23 km. covered in 16 minutes, i.e. at an average speed of 87 km. (54.1 miles) an hour

(1) The leading dimensions were :

'linders — 3.	0.524 × 0.630 m. (20 5/8" × 24 25/32").
'ate area	4.39 m² (47.4 sq. ft.).
eating surface	259.8 m² (2 799 sq. ft.).
iler pressure.	14 kgr./cm² (199 lb./sq. in.).
nder : wheel diameter	1.00 m. (3' 3 3/8").
ater capacity.	20 m³ (4 400 Br. gall.).
el capacity	7 tons.
eight.	About 57 t. (56 Engl. tons).
heel diameter.	1 m. and 2.20 m. (3' 3 3/8" and 7' 2 5/8").
heelbase :	
rigid.	2.56 m. (8' 5").
otal	11.485 m. (37' 8").
eight :	
n working order	86 t. ,84.6 Engl. tons).
dhesive.	32 t. (31.5 Engl. tons).
mpty	77 t. (76.2 Engl. tons).

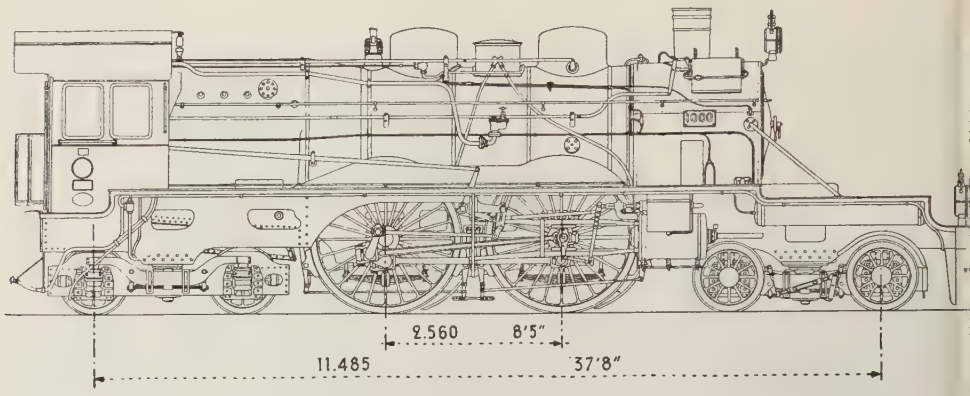

Fig. 418. — Old 4-4-4 *Henschel* locomotive as rebuilt and with casing removed.

with a maximum speed of 128 km. (79.5 miles). With a three-coach train weighing 108 t. (106.4 Engl. tons) a speed of 137 km. an hour (85.1 miles) was reached.

At 130 km. (80.8 miles) an hour, the indicated horse-power developed was 1 400. The streamlining was considered to have saved 250 to 300 H.P. (1). Later, this locomotive appears to have hauled on the Spandau-Hanover line, a 160-t. (157 Engl. tons) train at a maximum speed of 155 km. (96.3 miles) an hour.

Since 1932, the *Borsig Locomotive Works* have carried out a series of air resistance tests under the guidance of Professor Föttinger, and more recently, the German State has continued them at the *Kaiser Wilhelm Institute*, of Göttingen.

The *Reichsbahn* next asked certa German builders to submit designs f fast locomotives to haul 250-t. (246 En tons) trains at a speed of 150 km. (miles) an hour.

To check these designs and find c the heating effect of encasing the m tion, a standard class 03 *Pacific* locor tive was cased in by Messrs. *Borsig* (f 419) and it was found that the rise temperature in the bearings was o 30° C. (54° F.), while the streamlini of the motion saved 150 to 200 H.P. 140 km. (87 miles) an hour, correspo ing to an increase in power of 20 % the drawbar.

Resuming their earlier investigatio Messrs. *Henschel* designed several hi speed streamlined locomotives able compete with the diesel rakes.

The first *Henschel 4-6-4 locomotive*

(1) This locomotive consumed 3 530 lb. of coal per hour and was shown at the *Louisiana Purchase Exhibition* in 1904.

(2) The leading dimensions are :

Diameter of wheels .	2.30 m. (7' 6 9/16").	Boiler pressure. . .	20 kgr./cm² (284 lb./sq. in
Back wheels. . . .	1.35 m. (4' 4 1/2").		
Coupled wheelbase. .	2.70 m. (8' 9").	Weight in service . .	90 t. (88.6 Engl. to
Bogie wheelbase . .	2.50 m. (8' 2 7/17").	Adhesive weight . .	40 t. (39.4 Engl. to
Total wheelbase . .	10.50 m. (34' 5 7/16").	Weight of coaches .	65 t. (64.0 Engl. to

Fig. 419. — *Borsig* experimental streamlined locomotive.

Fig. 420. — Partly streamlined 4-6-0 *Great Western Ry.* locomotive.

was partly streamlined, or, more accurately, fitted with wind screens designed in accordance with modern principles to protect the smoke box, chimney, dome and front of the cab, and to a smaller extent, the front of the bogies.

Apart from the wheels, another new locomotive and tender were fitted with a complete streamlined casing (fig. 425). As with the 1904 locomotive, the cab is over the leading bogie, but this locomotive differs from the former in that it runs with the firebox end foremost and the smokebox in the rear.

Finally, a completely streamlined train has been designed, built and put into service between Berlin and Dresden.

Since the German Railways showed the way, a number of other railways have followed suite. The *Great Western Ry.* (England) made some partial tests (fig. 420), but the results, as might have bee expected, were not such as to justify an further expenditure.

The NETHERLANDS RAILWAYS investiga ed the question more thoroughly whe in February 1936, an old 4-cylinder *Ten Wheel* locomotive was cased in (fig 423) (1). They came to the conclusio that the efficacy of the streamlining wa little impaired if the driving axles wer left uncovered below the frame, so tha the motion was accessible (2). Althoug it increased the total weight by a coupl of tons, the fuel saved at a speed of 10 km. (62 miles)an hour was estimated a 20 % (3).

Early in 1935, the *P.L.M. Ry. Co* streamlined two complete trains (fig 422), the first of which was put int service between Paris and Lyons and in

(1) The leading dimensions are (fig. 422) :

Cylinders — diameter	400 mm. (15 3/4").
— stroke	660 mm. (26").
Boiler pressure	12 kgr./cm² (170 lb./sq. in).
Grate area	2.84 m² (30.6 sq. ft.).
Heating surface	145 m² (1 561 sq. ft.).
Superheating surface	41 m² (441 sq. ft.).
Wheels, diameter	0.930 m. (3' 5/8").
Do. do.	1.850 m. (6' 1").
Bogie wheelbase	2.100 m. (6' 10 11/16").
Coupled wheelbase	4.200 m. (13' 9 11/32").
Total wheelbase	8.650 m. (28' 4 35/64").
Overal dimensions :	
height	4.407 m. (14' 5 1/2").
length	18.980 m. (62' 3 9/32").
Tender :	
Water	18 m³ (3 960 Br. gall.).
Coal	6 tons.
Weight in working order	75 t. (73.8 Engl. tons).
Adhesive weight	49.5 t. (48.7 Engl. tons).
Weight empty	69 t. (67.9 Engl. tons).
Weight of tender in working order	44 t. (13.3 Engl. tons).

(2) The casing with the necessary inspection doors was built of rolled sections, electrically welded, the plates being riveted.

(3) With a dynamometer-car and brake van, at 100 km. (62 miles) an hour and compared with a non-streamlined locomotive, the gain was 120 H.P. with 20 p. c. constant admission into the cylinders.

Fig. 421. — *P.L.M.* streamlined locomotive.

Fig. 422. — *P.L.M. Rys.*' streamlined steam train.

luded at first a compound *Atlantic* locomotive (fig. 421), 29 years old [1], with a new 30 m³ (6 600 Br. gall.) capacity tender and three coaches, to which an *Inter-*

(1) Here are some of the leading dimensions of this locomotive :

Overall dimensions :	
length	12.030 m. + 9.460 m. (39' 6" + 31' 7/16").
width	2.950 m. (9' 8 5/32").
Diameter of wheels	2 m. (6' 6 3/4").
Wheelbase :	
rigid.	2.10 m. (6' 10 43/64").
total	8.08 m. (26' 6").
Weight :	
in working order	75.75 t. (74.6 Engl. tons).
adhesive	36.6 t. (36.0 Engl. tons)
tender	68.9 t. (67.8 Engl. tons)

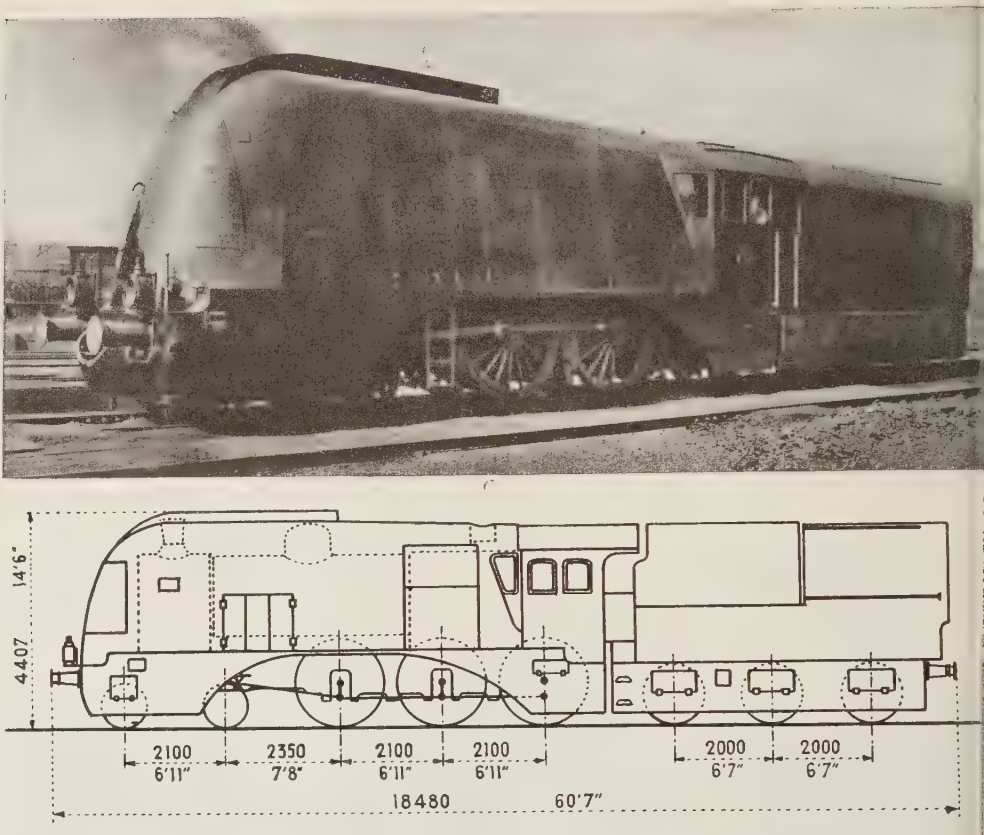

Fig. 423. — Dutch 4-6-0 cased-in locomotive.

national Sleeping-Car Company restaurant-car was afterwards added.

The weight of the train was thereby increased from 146 to 201 t., (143.7 to 196.9 Engl. tons), for 228 seats, as follows : 48 first class, 144 second class and 36 in the restaurant-car (1). With three coaches and the non-streamlined dynamometer car, the power required to maintain a speed of 140 km. (87 miles) an hour was 550 H.P. with a streamlined locomotive, and 650 with an ordinary one. This train, which replaced a Bugatti set, was timed at 120 km. (75 miles) an hour, whereas the railcar had been timed at 140 km. (87 miles). The locomotive only took water at Laroche. It has since been running from Paris as far as Marseilles.

Further streamlining has been carried out by a number of Railway Companies, the French *Nord, State, P.O.* and *Alsace*

(1) The first coach was 23.37 m. (76' 8") long overall; the second 22.50 m. (73' 10"). The outside width was 2.90 m. (9' 6 5/32"), the height 4.116 m. (13' 6").

Bogie wheelbase . . .	2.50 m. (8' 2' 7/16").
Distance between bogie centres	15.490 m. (50' 10").
Diameter of wheels. .	0.92 m. (3' 1/4").

Lorraine Ry. Cos. the *Hungarian State Rys.*, etc, and also several Railways in Canada, the United States, Australia and South Africa, as well as in Japan and Manchukuo.

LVII-3. — **Fast steam services.** — The results obtained during the trials were put into daily practice and average speeds have been gradually increased on a number of lines.

a) Berlin-Hamburg line. — The first-ultra fast trains were run on the Berlin-Hamburg line when the « Fliegende Hamburger » was out of service for repairs or overhauling. On such occasions, an *FD* train took its place to a slightly easier timing. Apart from this, another *FD* train (No. 23/24) runs between Hamburg and Berlin in 2 h. 25 m. on the down and 2 h. 24 m. on the up journey. It usually has 4 coaches and a non-streamlined dining car, and weighs 210 t. (207 Engl. tons). One of the two streamlined high-speed *Borsig* locomotives, built by this firm in conjunction with the *Reichsbahn's* engineers, heads it.

These 4-8-4 class 05 locomotives with 4- and 6-wheel tender bogies (fig. 424) were to haul 5-coach trains weighing 250 t. (246 Engl. tons) with a seating capacity of 250 to 300 passengers at a speed of 150 km. (93 miles) an hour, which might be increased to 175 km. (108.7 miles) an hour when developping 2 500 to 3 000 h.p. They are three-cylinder simple-expansion locomotives with a boiler pressure of 20 kgr./cm² (284 l./sq. in. (steam temperature 410° C. = 770° F.) and driving wheels 2.30 m. (7' 6 9/16") in diameter (1).

Owing to quick acceleration, they reach a speed of 170 km. (105.6 miles) an hour in 8 or 9 minutes, only 1 or 2 minutes

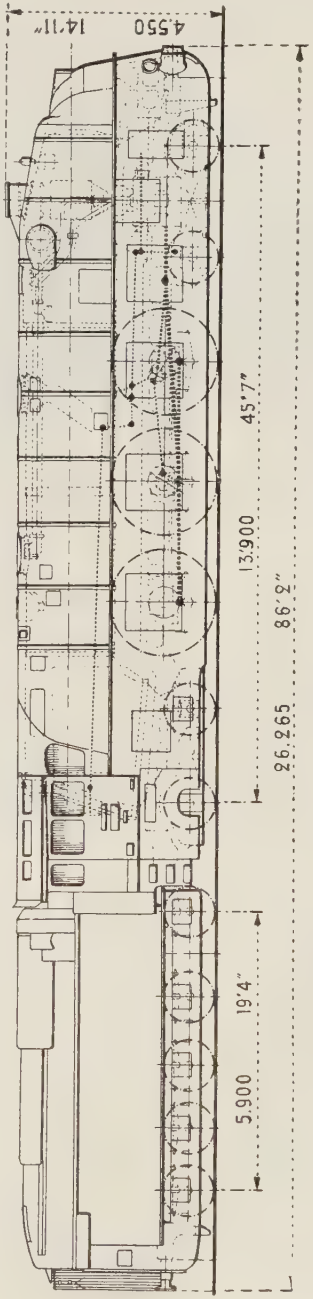

Fig. 424 (*). — Streamlined 4-6-4 locomotive built by the *Borsig* Works.

(*) From *The Railway Gazette*, London.

(1) See footnote on following page.

more than the diesels or electric trains. Over the first 17 km. (10.6 miles) they take but 2 or 3 minutes more than if they were running at full speed.

During the tests, in the first quarter of 1935, the two *Borsig* locomotives reached speeds of 181 km. (112.5 miles) an hour on the Berlin-Hamburg line and 192 km. (119.3 miles) an hour on the Berlin-Magdeburg line. With a light train they could work to the same timings as the diesels. This occurred on the journey made by members of the *Institution of Locomotive Engineers* between Berlin and Hamburg (fig. 410). In spite of several stops and speed restrictions, the locomotive maintained over more than 400 km. (250 miles) (outward and return runs combined) an average speed exceeding 146 km. (90.7 miles) an hour with a maximum of 178 km. (110.6 miles). Had there been no speed restrictions the total time would have been 2 h. 13 m., which is 4 minutes less than the « Fliegende Hamburger ».

On the 30th May 1936, with three coaches weighing in all 400 t. (394 Engl. tons), a special train maintained over a considerable distance a speed of 160 km. (100 miles) with a maximum of 184 km. (114.3 miles). The train was stoppe from a speed of 100 miles an hour i 1 400 m. (1 530 yards). Inversely it too 2 m. 18 s. to cover 1 800 m. (11.2 miles and the next kilometres were covered suc cessively in 37, 34.6, 31.6, 28, 27 and 2 seconds. A speed of 96 km. (59.65 miles an hour, was reached after 2.5 km. (1.5 miles) had been run; 114 km. (70.8 mi les) after 3.2 km. (2.0 miles), 128.8 km (80 miles) after 6.4 km. (4 miles) an 155 km. (96.3 miles), in 7 m. 52 s. A a speed of 150 km. (93 miles), an hour the streamlining was estimated to hav saved 20 % in power.

An alternative to the original schem consisted in the use of pulverised coal the first high-speed locomotive built t burn this fuel has just been delivered Reverting to the ideas of 1904, its bogi carries the cab.

THE DRESDEN-BERLIN LINE. — Among the innovations that came into force wit the introduction of the 15th May 193 timetables, appeared the first really fa Berlin-Dresden expresses. These wer *Henschel-Wegmann* trains with Scha fenberg couplings. Like the *Borsi* tender locomotives on the Hambur

(1) The leading dimensions are :

Cylinders :	
diameter	450 mm. (17 11/16").
stroke	660 mm. (26").
Boiler pressure	20 kgr./cm² (284 lb./sq. in.).
Grate area	4.7 m² (50.5 sq. ft.).
Heating surface	256 m² (275 sq. ft.).
Superheating surface	90 m² (969 sq. ft.).
Diameter of wheels	2.30 m. (7' 6 9/16").
Do.	1.10 m. (3' 7 5/16").
Weight in working order	126.7 t. (124.7 Engl. tons).
Adhesive weight	56.3 t. (55.4 Engl. tons).
Tender weight	57.6 t. (56.7 Engl. tons).
Fuel capacity	10 tons.
Water capacity	37 m³ (8 140 Br. gall.).
Wheelbase :	
rigid	5.10 m. (16' 8 15/32").
total	13.90 m. (45' 7 43/64").
bogie	2.30 and 2.0 m. (7' 6 9/16" and 6' 6 3/4").

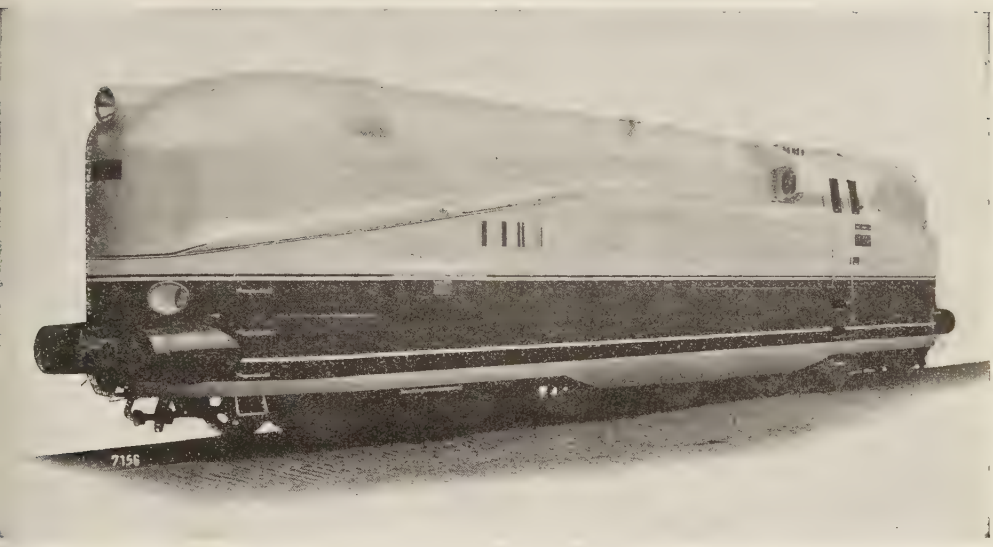

Fig. 425. — Streamlined 4-6-4 tank locomotive built by Messrs. *Henschel*.

line, the tank engines on the Dresden line have a 4-6-4 wheel arrangement (1) (fig. 425), but, as we have already pointed out, a tank engine and a tender locomotive differ essentially as, owing to the presence of the cab and bunkers, the tank engine should be likened to a 4-6-0 and not to a 4-6-4 tender locomotive. In the case under consideration, the tender locomotive's firebox is over the trailing bogie, while the tank engine's is over the third pair of drivers.

The two 4-6-5-T class 61 *Henschel* locomotives haul four light 30 to 32-t. (29.5 to 31.5 Engl. tons) vehicles, at a speed of 160 to 170 km. (100 to 106 miles) an

(1) Leading dimensions :

Cylinders :	
bore	460 mm. (18 1/8").
stroke	750 mm. (29 1/2").
Boiler pressure	20 kgr./cm² (284 lb./sq. in.).
Grate area	2.75 m² (29.6 sq. ft.).
Heating surface	151.9 m² (1 635 sq. ft.).
Superheating surface	69.2 m² (745 sq. ft.).
Wheels, diameter	2.30 m. (7' 6 9/16").
Do.	1.10 m. (3' 7 5/16").
Wheelbase :	
coupled	5.10 m. (16' 8 5/32").
total	14.35 m. (47' 1").
bogie	2.35 m. (7' 8 1/2").
Fuel capacity	5 tons.
Water capacity	16.5 m³ (3 630 Br. gall.).
Weight :	
in working order	128.3 t. (126.3 Engl. tons).
adhesive	55.6 t. (54.7 Engl. tons).
empty	99.7 t. (98.1 Engl. tons).

hour and run through curves of 180 m. (9 chains) radius. They are more or less symmetrically streamlined so as to run both ways at the same speed. It should also be noted that the running of this train puts an end to the old contention that tank engines are less steady at high speeds than are tender locomotives.

Until more precise results have been obtained in practice more especially concerning working costs, the services have not been speeded up further, although they certainly could.

LVII-4. — **Fastest runs.** — As high speeds are very general in Germany, apart from the average speeds reached, including stops, over the whole of the journey, we shall only quote sections of line having trains whose overall speed reaches at least 95 km. (59 miles) an hour and, in the case of diesels, 100 km. (62 miles). Even so, the tables are impressive.

The cartogram (fig. 426) shows all *D* train lines with highest average speed; it completes table 331 which also includes average speeds under 95 km. (59 miles) an hour.

Thanks to her diesels, Germany holds the World speed record. As regards steam traction, the Berlin and Hamburg train is beaten by 1/3 km. (0.2 mile) per hour only, by the *Pennsylvania Railroad* « Detroit Arrow », whose overall speed from Fort Mayne to Garry (198 km. = 123 miles) is 119.9 km. (74.5 miles) an hour, instead of the 119.6 km. (74.3 miles of the German train.

LVII-5. — **Long non-stop runs.** — Though Germany has only recently endeavoured to speed up her train services, she has for a long time been extending her non-stop runs. In May 1900 the longest German non-stop run occurred from Munich to Nuremberg (199 km. = 123.7 miles); it was then made in 2 h. 50 m., i.e. at a speed of 70.1 km. (43.6 miles) an hour.

In May 1905 the record passed to the *Prussian State Rys.*, over the 254 km. (157.8 miles) from Berlin to Hanover, but there was a two-minute service stop at Oebisfelde, which divided the run into two sections of 166 and 88 km. (103.1 and 54.7 miles) respectively. So as to avoid stopping, careful investigation of the *London and North Western* Ramsbottom troughs which a number of other railways were using, was made (1) They were rejected in favour of larger 20 to 31 m³ (4 400 to 6 820 Br. gall.) capacity tenders and water-saving Schmidt superheaters. These new tenders, introduced in 1909, enabled the locomotives to accomplish the entire run non-stop.

Since May 1911, further non-stop runs, each longer than the Berlin-Hanover, were introduced :

Berlin-Hamburg . . . 286 km. (177.7 miles).
Berlin-Liegnitz . . . 287 km. (178.3 miles).

Care must, however, be taken in the consideration of non-stop runs and above all, when comparing them with each other.

For example, the Swiss timetables for the 1931 summer shew train No. 487 as leaving Bellinzona at 7.54 p.m. and arriving at Lucerne 3 h. 26 m. later without having made any intermediate stop. Actually, a 4-minute stop occurred at Biasca and another, of 5 minutes duration, at Airolo; on the return journey (train No. 488) there was a 6-minute stop at Erstfeld to change locomotives, a 5-minute one at Göschenen to take water, and a

(1) They were tried in France, on the *State Rys.*, the *Nord* and the *P.L.M.*, and in the United States, on the *New York Central*, the *Pennsylvania*, etc.

Légende.
Km/h
140
130
120
110
100
90
80
70
60
moins de 60
Westerland
Niebüll
Padborg
Flensburg
Schleswig
Husum
Kiel
Eutin
Neumünster
Lübeck
Elmshorn
Cuxhaven
Norddeich
Wilhelmshaven
Emden
Wesermünde
Bremen
Hamburg
Ratzeburg
Wismar
Warnemünde
Rostock
Bad Doberan
Saßnitz
Stralsund
Greifswald
Demmin
Stettin
Swinemünde
Kolberg
Köslin
Lauenburg
Zoppot
Danzig
Dirschau
Elbing
Marienburg
Cranz
Tilsit
Insterburg
Königsberg
Eydtkuhnen
Gumbinnen
Stallupönen
Gerdauen
Korschen
Lyck
Rastenburg
Allenstein
Osterode
Deutsch Eylau
Furchau
Konitz (Chojnice)
Schneidemühl
Landsberg
Küstrin
Berlin
Potsdam
Frankfurt
Neu Bentschen
Rothenburg
Grünberg
Sommerfeld
Neusalz
Glogau
Sagan
Brachenberg
Militsch
Elsterwerda
Cottbus
Lübben
Falkenberg
Jüterbog
Wittenberg
Angermünde
Neu Strelitz
Neu Brandenburg
Pasewalk
Schwerin
Hagenow
Ludwigslust
Warren
Soltau
Uelzen
Verden
Salzwedel
Stendal
Magdeburg
Oschersleben
Halberstadt
Braunschweig
Hannover
Lehrte
Celle
Uelzen
Bentheim
Rheine
Osnabrück
Löhne
Emmerich
Cleve
Wesel
Münster
Hamm
Altenbeken
Hameln
Hildesheim
Soest
Dortmund
Kreiensen
Goslar
Northeim
Göttingen
Warburg
Kassel
Eichenberg
Witten
Hagen
Wuppertal
Neuss
Düsseldorf
Duisburg
Krefeld
Mönchengladbach
Aachen
Kohln
Siegen
Westerwald
Eisenach
Gotha
Erfurt
Weimar
Jena
Saalfeld
Zeitz
Leipzig
Halle
Dessau
Dresden
Bautzen
Görlitz
Kohlfurt
Liegnitz
Hirschberg
Breslau
Oels
Königszelt
Beuthen
Oppeln
Neisse
Glatz
Bad Kudowa
Mittelwalde
Heydebreck
Kattowitz
Lindenburg
Beuthen
Bohumin
Podmoky
Oranzahl
Chemnitz
Zwickau
Plauen
Hof
Eger
Schwandorf
Fürth
Regensburg
Ingolstadt
Landshut
Passau
Mühldorf
München
Augsburg
Ulm
Buchloe
Kempten
Immenstadt
Lindau
Friedrichshafen
Konstanz
Waldshut
Basel
Schaffhausen
Singen
Donaueschingen
Tuttlingen
Freiburg
Offenburg
Kehl
Appenweier
Freudenstadt
Tübingen
Rastatt
Baden Baden
Karlsruhe
Bruchsal
Heilbronn
Stuttgart
Aalen
Crailsheim
Nördlingen
Treuchtlingen
Heidenheim
Neumarkt
Bayreuth
Bamberg
Würzburg
Schweinfurt
Bad Kissingen
Hanau
Frankfurt
Wiesbaden
Darmstadt
Aschaffenburg
Seligenstadt
Mannheim
Worms
Speyer
Neustadt
Landau
Saarbrücken
Metzig
Trier
Kochem
Koblenz
Neuwied
Giessen
Marburg
Garmisch-Partenkirchen
Kufstein
Berchtesgaden
Bad Reichenhall
Salzburg
Hallein
Salzburg
Schaffhausen
Waldshut
Konstanz
Friedrichshafen
Lindau
Immenstadt
Kempten
Buchloe
Augsburg
München
Mühldorf
Landshut
Passau
Regensburg
Schwandorf
Fürth
Crailsheim
Aalen
Heidenheim
Nördlingen
Treuchtlingen
Ingolstadt
Neumarkt
Bayreuth
Bamberg
Würzburg
Schweinfurt
Bad Kissingen
Hanau
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Aschaffenburg
Seligenstadt
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Landau
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Chemnitz
Oranzahl
Podmoky
Dresden
Bautzen
Görlitz
Kohlfurt
Liegnitz
Hirschberg
Breslau
Oels
Königszelt
Beuthen
Oppeln
Neisse
Glatz
Bad Kudowa
Mittelwalde
Heydebreck
Kattowitz
Lindenburg
Beuthen
Bohumin
Elsterwerda
Cottbus
Falkenberg
Jüterbog
Zerbst
Dessau
Bernburg
Halle
Leipzig
Sangerhausen
Weissenfels
Eisenach
Gotha
Erfurt
Weimar
Jena
Saalfeld
Zeitz
Eichenberg
Kassel
Marburg
Warburg
Göttingen
Northeim
Kreiensen
Goslar
Hildesheim
Braunschweig
Hannover
Lehrte
Celle
Uelzen
Soltau
Verden
Uelzen
Salzwedel
Stendal
Magdeburg
Oschersleben
Halberstadt
Wittenberg
Angermünde
Neu Strelitz
Neu Brandenburg
Pasewalk
Schwerin
Hagenow
Ludwigslust
Warren
Ratzeburg
Wismar
Warnemünde
Rostock
Bad Doberan
Saßnitz
Stralsund
Greifswald
Demmin
Stettin
Swinemünde
Kolberg
Köslin
Lauenburg
Zoppot
Danzig
Dirschau
Elbing
Marienburg
Cranz
Tilsit
Insterburg
Königsberg
Eydtkuhnen
Gumbinnen
Stallupönen
Gerdauen
Korschen
Lyck
Rastenburg
Allenstein
Osterode
Deutsch Eylau
Furchau
Konitz (Chojnice)
Schneidemühl
Landsberg
Küstrin
Berlin
Potsdam
Frankfurt
Neu Bentschen
Rothenburg
Grünberg
Sommerfeld
Neusalz
Glogau
Sagan
Brachenberg
Militsch
Elsterwerda
Cottbus
Lübben

TABLE 331.

THE FASTEST GERMAN TRAIN RUNS.

(We have quoted all the sections of line run over non-stop at an overall speed exceeding 100 km. (62 miles) an hour.

RUN.	Distance.		Time of departure.	Time spent.	Speed		Trains	
	Km.	Miles.			Km./h.	M.p.h.		
Berlin Lehrter Bhf.-Hamburg	287	178.3	6.15 p. m.	2.24	119.6	74.3	*FD*	24
Berlin Anh.-Dresden-Neustadt.	176	109.4	R 9.37 a. m.	1.35	111.0	69.0	*D*	53
(Berlin) Postdam-Magdeburg	116	72.1	8.17 a. m.	1.06	105.5	65.6	*D*	178
(Berlin Schl.) Küstrin-Neustadt-Schneidemühl.	161	100.0	R 7.44 p. m.	1.32	105.0	65.3	*D*	44
Berlin-Anhalt-Halle	162	100.7	10.35 a. m.	1.33	104.5	64.9	*FD*	80
(Berlin Schl.) Schneidemühl-Konitz	83	51.6	R 11.28 a. m.	0.48	103.8	64.4	*D*	16
(Berlin Schl.) Oppeln-Brieg	41	25.5	9.23 a. m.	0.24	102.5	63.7	*D*	32
(Hamburg) Harburg-Bremen	104	64.6	R 1.51 p. m.	1.01	102.3	63.6	*D*	211
Berlin Anhalt-Leipzig.	165	102.5	R 7.18 p. m.	1.37	102.1	63.4	*FD*	5
(Berlin Zoo.) Minden-Bielefeld	46	28 6	R 1.10 a. m.	0.27	102.1	63.4	*D*	9
(Do.) Hanover-Hamm.	177	110.0	6.38 p. m.	1.45	101 2	62.9	*FD*	22
(Do.) Spandau-Stendal	93	57.8	9.55 a. m.	0.54	101.1	62.8	*D*	2
(Berlin Schl.) Liegnitz-Breslau	65	40.4	R 6.00 a. m.	0.39	100.0	62.1	*D*	118
ELECTRIC TRACTION.								
(Stuttgart) Ulm-Augsburg.	86	53.4		0.46	112.2	69.7	*FDt*	723
(Do.) Augsburg-Munich.	62	38.5	R 7.00 a. m.	0.33	112.1	69.6	*FDt*	720
Breslau-Königszelt	49	30.4	9.11 a. m.	0.27	108.9	67.7	*D*	192
(Berlin Anh.) Nuremberg-Augsburg	137	85.1	R 12.44 p. m.	1.20	102.8	63.9	*FD*	79
DIESEL RAILCARS.								
(Berlin Zoo) Hanover-Hamm	177	110.0	R 8.44 a. m.	1.20	137.9	85.7	*FDt*	15
Berlin Zoo-Hanover	254	157.8	7.22 p. m.	1.56	131.4	81.6	*FDt*	116
Berlin Anhalt-Leipzig.	165	102.5	R 10.30 a. m.	1.16	130.3	81.0	*FDt*	571
Berlin Lehrter Bhf.-Hamburg	287	178.3	5.06 p. m.	2.17	125.7	78.1	*FDt*	2
Berlin Schl.-Sagan-Sorau-Breslau.	341	211.9	8.31 p. m.	2.39	124.2	77.2	*FDt*	45
Hamburg-Bremen	119	73.9	7.51 p. m.	0.58	123.1	76.5	*FDt*	38
(Berlin)- Breslau-Oppeln	82	51.0	11.13 p. m.	0 41	120.0	74.6	*FDt*	45
Hamburg-Bremen (Cologne)	115	71.5	7.51 p. m.	0.58	118.9	73.9	*FDt*	38
(Hamburg) Bremen-Osnabrück	122	75.8	R 9.33 a. m.	1.02	118.1	73.4	*Do.*	
(Berlin) Oppeln-Heydebreck	41	25.5	11.55 p. m.	0.21	117.1	72.8	*Do.*	
(Do.) Heydebreck-Gleiwitz	37	23.0	12.17 a. m.	0.19	116.8	72.6	*Do.*	
(Berlin) Nuremberg-Treucht. Munich	199	123.7	9.58 p. m.	1.44	113.8	70.7	*EDt*	552
(Hamburg) Osnabrück-Münster	50	31 1	9.54 p. m.	0.27	111.1	69.0	*FDt*	38
(Berlin) Erfurt-Frankfort/M.	269	167.2	9.00 p. m.	2.27	109.8	68.2	*FDt*	572
(Do.) Hamm-Dortmund	31	19 3	10.40 p. m.	0.17	109.4	68.0	*FDt*	16
(Do.) Weissenfels-Erfurt	76	47.2	9.13 p. m.	0.45	101.3	62.9	*FDt*	572
(Do.) Münster-Hamm.	35	21.7	10.22 p. m.	0.21	100.0	62.1	*FDt*	38

urther 2-minute stop at Biasca to change ie engine crew (1).

In 1912, the various Administrations improved their services (See table 332).

TABLE 332.

LONG NON-STOP RUNS MADE IN 1912.

ADMINISTRATION	RUN.	Distance.		Time of departure.	Speed.	
		Km.	Miles.		Km./h.	M. p.h.
Prussian State Rys. . .	Berlin-Hamburg. . . .	286.8	178.2	3.14	88.7	55.1
Bavarian State Rys. . .	Munich-Würzburg . . .	277.1	172.2	3.25	81.1	50.4
Mecklemburg St. Rys. .	Rostock-Lübeck. . . .	133.2	82.8	1.57	68 3	42.4
Alsace and Palatinate .	Ludwigshafen-Strasbourg .	129.9	80.7	1.40	77.9	48.4
Prussian and Bavarian State Rys.	Nuremberg-Halle (2) . .	313.9	195.0	4.31	69.5	43.2

Some of these included service stops. hus on the Halle-Nuremberg run of the erlin-Munich *FD* trains, a banking lo- omotive was added over the Probstzella- othenkirchen section, causing the down ains to stop at Probstzella (318.5 km. = 197.9 miles from Berlin) and the up ains, at Rothenkirchen (343.9 km. or 13.7 miles).

The Nuremberg-Stuttgart run was si- ilarly broken into at Crailsheim for ignalling purposes.

In the same way, the Schneidemühl- Iarienburg run, during which the Polish orridor is traversed, has frontier service tops at Konitz and at Dirschau, so as to allow the substitution of Polish for German locomotives.

In the first column of table 333, where we give the departure station, we have added brackets, when the journey actually begins elsewhere. It is thus possible to see at a glance where the journey occurs, and whether the run is part of a radiating or a cross-country service.

LVII-6. — **Conclusions.** — To sum up, table 334 gives the mileage of lines covered by the fastest trains, at various average speeds. With her 2 681 km. (1 669 miles) run over at speeds exceeding 100 km. (62 miles) an hour, Germany

(1) This is due to the 1 in 40 to 1 in 37 gradients between Erstfeld and Göschenen, which could only be negotiated single headed at a speed of 29 km. (18 miles) an hour, increased to 45.6 km. (28.3 miles) between Biasca and Airolo; a service stop was inserted on the first section and a second at Biasca.

When the Erstfeld-Bellinzona run is worked by the same gradient locomotive, there are two intermediate service stops, one at Göschenen to take water, and the other at Biasca to change the engine crew.

Actually the longest non-stop section of the run was the 105.1 km. (65.3 miles) one from Airolo to Lucerne; the train left at 7.54 p.m. and took 2 hours for the journey, which it accomplished at an average speed of 49 km. (30.4 miles) an hour.

For some years, the « Riviera Express » has run non-stop from Basle to Bellinzona, 263 km. (163 miles). Since the 22nd May 1937, it has been diverted from the Basle—Olten—Lucerne—Arth-Goldau to the Basle—Olten—Aarau—Rothkreuz—Arth-Goldau route, which shortens the distance by 8 km. (5 miles). No service stops are included.

(2) Since 1st June 1912.

TABLE 333.

LONGEST NON-STOP RUNS (OVER 150 KM. = 93 MILES).

RUN.	Distance.		Time of departure.	Time spent.	Speed.		Train
	Km.	Miles.			Km./h.	M.p.h.	
Steam traction.							
(Berlin Anhalt) Halle-Nuremberg .	314	195.1	12.15 p. m.	4.00	78.5	48 8	*FD* 80
Berlin Lehrter Bhf.-Hamburg . . .	287	178.3	6.15 p. m.	2 24	119.6	74.3	*FD* 24
Munich-Würzburg (Frankfort). . .	277	172.1	9.20 a. m.	3 03	90.8	56.4	*FD* 263
(Berlin) Erfurt-Frankfort/M. . . .	264	164.0	R 2.40 p. m.	3.00	88.0	54.7	*FD* 5
Berlin Zoo-Hanover (Cologne) . . .	254	157.8	3.58 p. m.	2.33	99.6	61.9	*FD* 22
(Berlin Schl.) Schneidemühl-Marienburg	198(1)	123.0	7.31 p. m.	2.28	80.4	50.0	*D* 15
Cologne L.B.-Mayence (Basle) . . .	186	115.6	12.05 p. m.	2 06	88.6	55.1	*FD* 102 (Rhe
Cologne R.B.-Wiesbaden (Frankft/M.)	185(1)	115.0	R 2.54 a. m.	2 21	71.8	44 6	*L* 51 (Oster
(Berlin Anh.) Hof-Ratisbon	179	111 2	12.50 p. m.	2.41	66.6	41.4	*D* 322
(Berlin Zoo) Hanover-Hamm . . .	177	110.0	6.38 p. m.	1.45	101.2	62.9	*FD* 22
Berlin Anh.-Elsterwerda-Dresden N.	176	109.4	R 9.37 a. m.	1.35	111.0	69.0	*D* 53
Hamburg-Lehrte (Frankfort) . . .	165	102.5	R 6.19 a. m.	1.52	88.4	54.9	*D* 191
Berlin-Anhalt-Leipzig	165	102.5	R 7.18 p. m.	1.37	102.1	63.4	*FD* 5
Berlin Anh.-Halle (Munich) . . .	162	100.7	10.35 a. m.	1.33	104.5	64.9	*FD* 80
(Berlin Schl.) Küstrin N. (Scheidemühl)	161	100 0	R 7.44 p. m.	1.32	105.0	65 3	*D* 44
(Berlin Anh.) Erfurt-Schweinfurt. .	158	98.2	12.49 p. m.	2 26	64.9	40.3	*D* 10
Munich-Immenstadt.	153	95.1	R 6 15 p. m.	2.00	76.5	47.5	*D* 173
(Stuttgart) Nuremberg-Eger . . .	151	93.8	R 7.52 p. m.	2.04	73.0	45.4	*L* 106 Karl
Electric traction.							
(Strasbourg) Stuttgart-Munich . .	221	137.3	R 10.10 p. m.	2.47	79.4	49.3	*L* 6 Orien
(Strasbourg) Munich-Salzburg. . .	153	95.1	8.37 a. m.	1.52	81.9	50.9	*L* 5 Orien
Diesel railcars.							
Berlin Schl.-Sagan-Sorau-Breslau . .	341	211.9	8.31 p. m.	2.39	124 2	77.2	*FDt* 45
(Berlin Anh.) Leipzig-Nuremberg. .	322	200.1	6.27 p. m.	3.25	94.2	58.5	*FDt* 552
Berlin Lehrter-Hamburg	287	178.3	11.00 a. m.	2.17	125.7	78.1	*FDt* 2
(Berlin Anh.) Erfurt-Frankfort . .	269	167.2	9.00 p. m.	2.27	109.8	68.2	*FDt* 572
Berlin Zoo-Hanover (Cologne) . . .	254	157.8	7.22 p. m.	1.56	131.4	81.6	*FDt* 116
(Berlin Anh.) Nuremberg-Munich .	199	123.7	9.58 p. m.	1.44	113.8	70.7	*FDt* 552
(Saarbrücken) Treves-Cologne . . .	180	111.9	8.21 a m	2.36	69.3	43.1	*E* 151 Eilt
(Berlin Zoo) Hanover-Hamm . . .	177	110.0	R 8.44 a. m.	1.20	137.9	85.7	*FDt* 15
Berlin Anh.-Leipzig (Munich) . . .	165	102.5	5.06 p. m.	1.17	128.5	79.9	*FDt* 552

(1) With service stops.

holds the first place in Europe and the second in the World, for high-speed running, only the United States having a greater mileage.

Table 331 showing the highest speeds according to methods of traction neces sarily includes some of the runs twic over; the grand total cannot therefor be obtained, by simply adding them u

It is a noteworthy fact that over 2 20

n. (1 367.3 miles) of lines are operated diesels at over 100 km. (62 miles) an ur and only 148 km. (92 miles) lie to e credit of electric traction which, of urse, is mostly used in hilly districts. Most of the fast lines are worked at an erage speed of 60 to 90 km. (37.3 to 56 les) an hour, those between 70 and 80 n. (43.5 and 50 miles) being fewer an those between 80 and 90 (50 and miles). As elsewhere, the mileage rked at 90 to 100 km. (56 to 62 miles) hour is considerably less, this de- ease being more marked still between and 100 km. (59 and 62 miles), hereas the mileage increases rapidly beyond. This is easily accounted for. When it becomes desirable to increase speed on lines lying between the 80 and 90 km. (50 and 56 miles) limits, considerable improvement is made and the intermediate stage passed over.

In the future the position seems likely to be :

a) a large mileage of lines with speeds between 60 and 70 km. (37.3 and 43.5 miles);

b) another of fast trains between 80 and 90 km. (50 and 56 miles);

c) and one of ultra-fast trains, at over 100 km. (62 miles) an hour.

TABLE 334.

LENGTH OF GERMAN LINES RUN OVER AT VARIOUS OVERALL SPEEDS by the fastest trains worked over them.

SPEED. Km. (Miles) p. h.	Extent, in kilometres (in *miles*), of lines run over by						Percentage of whole system of 53 883 km (33 382 miles).
	FD, or *D* trains.		*E* trains (1).		Together.		
er 60 (37.5) . . .	98	(60.9)	329	(204.4)	427	(265.3)	0.8
to 69.9 (37.5 to 43.4)	4 895	(3 041.6)	1 801	(1 119.1)	6 696	(4 160.7)	12.4
to 79.9 (43.5 to 49.9)	3 829	(2 379.3)	925	(574.8)	4 754	(2 954.1)	8.6
to 89.9 (50.0 to 55.9) .	5 645	(3 395.8)	32	(19.9)	5 677	(3 527.7)	10.5
to 94.9 (56.0 to 58.9)	880	(546.8)	115	(71.5)	995	(618.3)	1.6
to 99.9 (59 to 61.9) .	662	(411.4)	...		662	(411.4)	1.2
to 109.9 (62 to 68.4) .	487	(302.6)	...		487	(302.6)	0.9
to 119.9 (68.5 to 74.9) .	888	(551.8)	...		888	(551.8)	1.6
to 129.9 (75.0 to 80.9)	875	(543.7)	...		875	(543.7)	1.6
to 139.9 (81.0 to 86.9)	431	(267.8)	...		431	(267.8)	0.9
Total. . .	18 690	(11 631.7)	3 202	(1 989.7)	21 892	(13 603.4)	40.1
o 89.9 (37.5 to 55.9)	14 369	(9 096.4)	2 758	(1 713.8)	17 127	(10 642.2)	31.8
100 (62)	2 681	(1 665.9)	...		2 681	(1 665.9)	5.0

(1) In this column we show the mileage of lines run over by *E* trains but not *D* or *D* trains. There are also *E* trains on the lines whose mileage is shown in the previous olumn (*D* and *FD* trains) but their speed is lower than that of the *D* trains in nearly very case, and the mileage remains the same even when this is not so, the only exception in this group being the 115 km. (71.5 miles) of the Berlin-Görlitz line, on which the gher speed of the *E* trains makes it pass from the 80 to 89.9 km. (50 to 55.9 miles) oup (where the *D* trains would put it) into the 90 to 94.5 km. (56 to 58.5 miles), due to e *E* trains. Therefore, we have only included it in the latter column. Obviously, the tal is not affected thereby.

CHAPTER LVIII.

Appendix.

LVIII-1. — **Lake navigation**, especially on the larger lakes, is of considerable importance when it completes the system of communication. The largest of these lakes is the Lake of Constance with an area of 540 km² (208.5 sq. miles) (1). Its situation on the borders of the States of Baden, Wurtemberg and Bavaria on the one hand, and Austria and Switzerland on the other, has considerably influenced the development of its traffic (fig. 427).

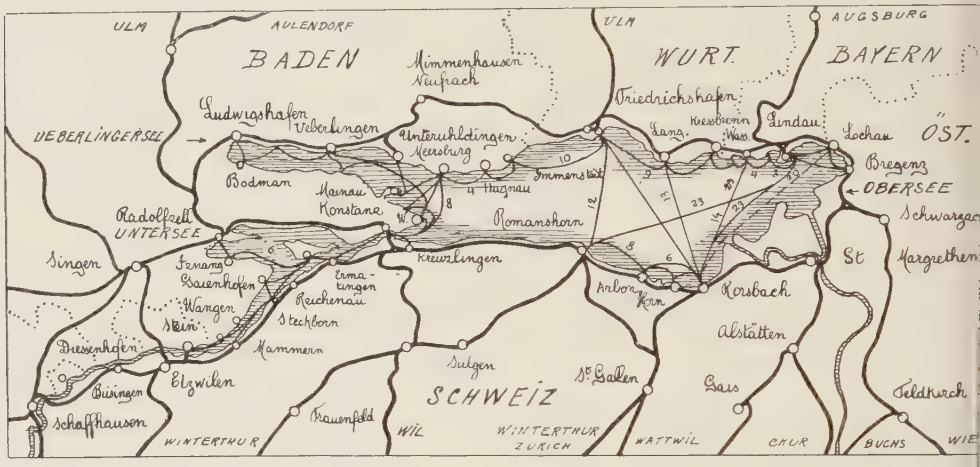

Fig. 427. — Lake of Constance rail and boat services.

Railway lines follow its shores and it is possible to go from Bregenz to Radolfzell, for example, either by rail along the northern shore (122 km. = 75.8 miles) or along the southern (82 km. = 60 miles) or by water. Besides this, it has been necessary to add a certain number of cross-lake services so as to link up important places lying opposite each other.

In 1826, ten years after steamers were first put on the Rhine, the first steam packets plied between Friedrichshafen (Wurt.) and Rorschach (Switzerland). A Baden Co. with headquarters at Constance followed in 1830, a Bavarian one in 1838 and a Swiss (Schaffhausen-Rorschach), in 1850 (2). Each of the States concerned soon added railways to the navigation services. In 1847, Wurtemberg opened its Friedrichshafen and

(1) Its greatest length, from Bregenz to Ludwigshafen, is 64 km. (40 miles), and its greatest width, from Rorschach to Kressborn, 14 km. (8.7 miles). The maximum depth of the Obersee is 251.8 m. (826 1/2') between Immenstadt and Romanshorn; that of the Überlingersee 147 m. (482'), and the Untersee 46.4 m. (152'), between Gaierhafen and Berlingen. At normal water level the area of the Übersee and the Überlingersee is 475 km² (183.5 sq. miles) and that of the Untersee 63.9 m² (24.7 sq. miles).

(2) Part of the information given here has been taken from Mr. NAGEL's excellent paper published in the *Zeitung des Vereins Mitteleuropäischer Eisenbahnverwaltungen*.

ensburg line which it extended in 1850 Stuttgart; Bavaria built a railway from indau to Augsburg and Munich in 1853 nd Baden, another in 1863, as far as onstance. After a time, each of the hree States bought up the existing navi-ation Companies.

In Switzerland, the *Swiss North East y. Co.* opened a line from Winterthur Romanshorn in 1857, besides main-aining a boat service as well, but in 864, it turned the latter over to the *wiss Navigation Co.* Not until a score f years later did an Austrian Naviga-on Co., with headquarters at Bregenz, art a steamer service; this was when he Arlberg Railway reached the Lake of onstance.

As may be noticed, all these railway lines ran perpendicularly to the Lake and in consequence, not only had the boats to link them up by services running along the shore, such as between Constance and Bregenz via the Swiss side and between Constance and Lindau, via the German, but they also had to give connections between the extremities of railways reaching opposite shores and to run cross services between Friedrichshafen and Lindau in the north, and Rorschach and Romanshorn, in the south. An agreement signed in 1885 between the *Swiss North East Rys. Co.* and the *Bavarian State Ry. Administration* gave the Lindau-Romanshorn line to the latter and retained the former as a joint service.

The development of the railway system

TABLE 335.

LAKE OF CONSTANCE (BODENSEE) PASSENGER BOAT SERVICES.

Non-stop trips are shown in **heavy type.**

RUN.	Distance		Time of departure.	Time spent.	Number of stops.	Speed		—
	Km.	Miles.				Km./h.	M.p.h.	
nce-Friedrichshafen-Bregenz.	59.5	37.0	5.35 a. m.	3.35	10	16.5	10.3	*Bodensee-schiffahrt.*
tance-Meersburg	8.0	5 0	Do.	0.25	...	19.2	11.9	...
rsburg-Lindau	17.3	10.8	6.10 a. m.	2.30	8	6.9	4.3	...
au-Bregenz	7.0	4.4	8.50 a. m.	0.20	...	21 0	13 0	...
CROSSINGS.								
ichshafen-Romanshorn	12.0	7.5	6.25 a. m.	0.40	...	18.0	11.2	...
ichshafen-Rorschach	20.8	12.9	11.30 a. m.	1.05	1	19.2	11.9	...
-Romanshorn	23.0	14.3	12.30 p. m.	1.08	...	20.0	12.4	...
-Rorschach	21.0	13.0	R 9.40 a. m.	1.07	2	18.8	11.7	...
	Do.	Do.	12.15 p. m.	0.55	...	22.9	14.2	...
shorn-Rorschach	14.0	8.7	2.52 p. m.	0.50	2	16.8	10.4	*Swiss Federal Rys.*
nce-Ludwigshafen	33.2	20 6	1.35 p. m.	1.25	8	23.4	14.5	*Reichsbahn.*
tance-Dingelsdorf	30.0	18.6	8.05 a. m.	1.40	5	18.0	11.2	Do.
tance-Überlingen	20.4	12.7	4.30 a. m.	0.50	...	24 5	15.2	Do.
ıouse-Reichenau	36.0	22.4	5.05 p. m.	2.30	3	14.4	8.9	*Swiss Co.*
	Do.	Do.	R 10.55 a. m.	1.45	2	20.6	12.8	Do.
ıau-Constance	12.0	7.5	3.00 p. m.	0.40	...	18.0	11.2	Do.

completely altered traffic conditions and had a particularly harmful effect on the longitudinal boat services. In 1872, the Bregenz-Lindau railway was completed, and in 1895, that on the south shore reached Constance and Schaffhausen. The boat services had to rely exclusively on local and tourist traffic and the Ludwigshafen and Überlingen service was discontinued.

The several navigation companies then came to a general pooling agreement applying originally to the German passenger services (1877). The Austrian Companies came in in 1866 and the Swiss Bregenz-Lindau, in 1902. These arrangements were further modified when the German State and the Helvetic Confederation took over the railways in their respective territories.

At the present time, the *Germano-Austrian Association* operates the boats along the northern shore (Bregenz-Meersburg-Constance), and the *Germano-Swiss Union*, the Lindau and Friedrichshafen to Rorschach cross services. The local lines are operated by each of the countries concerned and the lines serving ports in several countries, by international pooling committees.

Thus, in the first group there is only one Swiss Company (the *Arbon Association)* operating the Rorschach-Arbon-Romanshorn line, the *Reichsbahn* operates the Constance to Ludwigshafen — Überlingersee and the Radolfzell to Ohningen — Untersee lines and the *Schaffhausen Co.* operates a Rhine navigation service beyond.

In the second group, the *Germano-Swiss Union* operates the services from Lindau and Friedrichshafen to Rorschach and Romanshorn, while the *Germano-Austrian Company* operates the route along the northern shore, with call at Bregenz, Meersburg and Constance.

Although traffic improved for a lon time, the number of passengers increas ing from 444 430 in 1865 to 1 113 338 i 1895 and 2 240 000 in 1929, there ha since been a decline, partly atributabl to privately-owned motorboat service and these figures receded to 1 673 174 i 1931.

Many types of boats, mostly paddl steamers, are still in commission, rang ing from the 1887 « Greif » to the 192 « Stadt Uberlingen » which carries 1 20 passenger and the twin-screw « Algau (Lindau). The 1928 *Austrian Federal Ry* « Österreich » is a twin-screw 700-pa senger diesel boat. The 1932 *Swiss Fed ral Rys.* « Thurgau » brought the tot passenger fleet up to 31 units.

In winter, motorboats, such as th German « Kempten », « Augsburg » an the « Raversburg » (1931) which on carries 400 passengers, take the place the larger units.

Most of the passenger boats have speed of 20 km. (12.4 miles) an hour.

The goods traffic is chiefly worked b train ferries or lighters. In additio there is a cross-lake service for moto car traffic, between Friedrichshafen an Romanshorn.

Boats are also maintained on a numb of Bavarian lakes : the Schliersee, T gernsee, Wurmsee, Chiemsee and Am mersee, but these are merely local touri services.

LVIII-2. — **River navigation,** whi takes place on all the major German r vers, the Vistula, Oder, Elbe, Wes though sometimes only in the summer, particularly active on the Rhine, whi

LAKE OF CONSTANCE FLEET. — LEADING DIMENSIONS OF GERMAN MODERN CRAFT.

Type of boat.	12 paddle boats.	6 motor boats (+ 2 ordered).	8 motor boats.	3 train ferries.
Maximum length	50 m. — 60.5 m. (164' 1/2" — 197' 4")	47 m. — 60.5 m. (154' 2 3/8" — 197' 4")	16.60 m. — 42.20 m. (54' 5 1/2" — 138' 5")	43.60 m. — 54.40 m. (143' — 178' 6")
Maximum width	13.20 m. — 14.15 m. (43' 4" — 46' 5")	9 m. — 11.8 m. (29' 6 3/8"—38' 8 5/8")	4 m. — 7.20 m. (13' 1 1/2"— 23' 7 1/2")	...
Width of frame	6.40 m. — 8.26 m. (21' — 27' 1")	7.50 m. — 9 m. (24'7 9/32"—29'6 3/8')	3.10 m. — 6.70 m. (10' 2" — 22')	9.15 m. and 9.50 m. (30' and 31' 2")
Passengers carried.	550 to 1000	500 to 1 500	100 to 300	0 to 100
Useful load	...	...	...	250 t. and 320 t. (246 and 314.6 Engl. t.)
Water displacement, light	250 t. — 365 t. (245.6 — 358.6 Engl. t.)	200 t. — 400 t. (196.5 — 392 Engl. t.)	15 t. — 130 t. (14.7 — 127.7 Engl. t.)	140 t. and 294 t. (137.5 and 288.8 Engl. t.)
Do. , loaded	314 t. — 450 t. (308.5 — 442 Engl. t.)	230 t. — 510 t. (226 — 501 Engl. t.)	21 t. — 153 t. (20.6 — 150.3 Engl. t.)	390 t. and 624 t. (383 and 613 Engl. t.)
Number of tracks.	...	...	...	2
Number of wagons	...	...	...	8 to 10
Maximum draught	1.55 m. — 1.65 m. (5' 1" — 5' 5")	1.50 m. — 1.80 m. (4' 11" — 5' 11")	1 m. — 1.39 m. (3' 3 3/8"— 4' 6 23/32")	0.96 m. and 1.60 m. (3' 1 3//4" and 5' 3")
Maximum speed	23 km. — 28 km. (14.3 — 17.4 miles)	25 km. — 28 km. (15.5 — 17.4 miles)	17 km. — 26 km. (10.6 — 16.2 miles)	11 km. and 18 km. (6.8 and 11.2 miles)
Engines.	Compound steam engines, 2 and 3 cylinders, with condensation; 550 to 1 020 H.P.	Each with two 6 or 8-cylinder 4-stroke diesel engines, 2 × 230 or 2 × 450 H.P.	Either one or two 6-cylinder 4-stroke diesel engines, 60-560 H.P. per boat.	Each with two 6-cylinder 4-stroke diesel engines, 2 × 90 H.P. and 2 × 240 H.P.
	n = 43 — 64/min. each.	n = 265 — 520/min. each.	n = 290 — 600/min. each.	n = 420 and 320/min. each.
	2 boilers with double flame tubes, part for saturated, part for superheated steam; heating surface : 123 — 245 m² (1 323 — 2 637 sq. ft.) per boat; steam pressure 9.5 to 11.5 kgr./cm² (135 to 163 lb./sq. in.).	1 twin-screw boat. 5 boats with Voith-Schneider screw.	1 boat with Voith-Schneider screw. The others single-screw and twin-screw boats.	Twin-screw.

TABLE 337.

SPEED OF RIVER BOATS.

Trip.	Distance. Km.	Distance. Miles.	Time of departnre.	Time spent.	Number of stops.	Speed. Km./h.	Speed. M.p.h.	—
Cologne-Mayence . . .	200	124	7.30 a. m.	11.40	17	17.1	10.6	*Köln-Düsseldo Rheindampfschi* Schnellfahrt Ex
	200	124	R 9.15 a. m.	8.30	12	23.5	14.6	
St. Goar-Assmanshausen	29	...	R 11.10 a. m.	0.56	...	31.0	19.3	
Rüdesheim-Wiesbaden .	23	...	R 9.35 a. m.	1.05	...	21.2	13.2	
Coblence Rh.-Berncastel Cues	...	...	1.10 p. m.	0.40	...	...	...	*Mosel Perso schiffahrt*
	...	...	R 8.45 a. m.	0.40	...	...	...	
Heilbronn-Heidelberg . .	89	...	7.45 a. m.	9.25	19	9.4	5.8	*Neckarschiffa*

TABLE 338.

MOTORBUS SERVICES.

(Alternative railway services are shown *in italics).*

RUN.	Distance. Km.	Distance. Miles.	Time of departure.	Time spent.	Number of stops.	Speed. Km./h.	Speed. M.p.h.	—
Berlin Stett.-Angermünde-Stettin	152	94.4	6 00 a. m.	2.45	4	55.3	34.4	Auto I.
	135	*83.9*	*8.16* a. m.	*1.50*	...	*73.6*	*45.7*	*D. 21.*
Over autostrades.								
Frankfort-Darmstadt-Mannheim Hbf.	88.5	55 0	2.00 p. m.	1.23	2	64.1	39.8	*R.B.* Fast bus
Frankfort-Darmstadt Hbf.	33.2	20.6	8 30 a. m.	0.33	...	60.0	37 3	Do.
Darmstadt-Mannheim . .	55.3	34.4	2.34 p. m.	0.49	1	67.7	42.1	Do.
Frankfort-Mannheim Hbf. thr.	81.5	50.6	8.00 a. m.	1.23	1	58.9	36.6	Do.
Frankfort - Darmstadt - Heidelberg	...	...	7.30 a. m.	1.28	1	...	...	Do.
Darmstadt-Heidelberg Hb.	62 4	38.8	8.04 a. m.	0.54	...	69.3	43.1	Do.
Frankfort-Heidelberg (thr.)	88.6	55.0	9.00 a. m.	1.19	...	67.3	41.8	Do.
Mannheim-Heidelberg. . .	19.2	11 9	12.30 p. m.	0.21	1	54.3	33.7	Do.
Reichsbahn motorbuses.								
Munich-Tegernsee	54.0	33.6	7.40 a. m.	1.09	5	46.9	29.1	R.B. Motorbus
Munich-Neuhaus.	60.0	37.3	7.30 a. m.	1.23	7	43.4	27 0	Do.
Braunschweig-Hanover . .	61.0	37.9	3.03 p. m.	1.27	1	42.0	26.1	Do.
	61.0	*37.9*	*9.06 a. m.*	*0.51*	*2*	*71.7*	*44.6*	*E. 126.*

forms a great line of communication. The speed of the boats is very different up or down stream, and according as they are run as express or ordinary services.

LVIII-3. — **Reichsbahn motorbus services.** — The *Reichsbahn* has replaced certain trains by bus services; on the other hand, it has introduced buses on some of the autostrades. They differ from those in other countries by their high overall speed.

[621. 135 4 & 625. 215]

The formulæ used to calculate the additional tractiv resistance W_r on curves,

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A. — Preliminaries.

The railways as a rule select one of the many available formulæ for calculating the resistance w_r due to curves.

On the other hand, there is the general opinion that the bogie is an ingenious invention as it facilitates the running of vehicles through curves and therefore reduces the resistance w_r considerably. There is more or less general agreement that w_r is dependent on the gauge e of the track, on the wheelbase s of the vehicles, on the radius R of the curves, and on the coefficient of friction f between the tyres and rails.

In the present note, an endeavour will be made to give the elements e, s and f their proper values and to justify the use of a formula which takes them into account adequately and which can be used unhesitatingly in all cases.

The following example illustrates the importance of the matter.

When considering the stock of a standard-gauge railway we find it consists of :

(a) bogie carriages with bogie wheel bases of 2 m. to 2.50 m. (6' 6 3/4" to 8' 2 7/16");

(b) four- and six-wheeled carriages with a rigid wheelbase of 3.50 to 4.50 m. (11' 6" to 13' 9");

(c) wagons with a rigid wheelbase 3.25 m. to 6.50 m. (10' 8" to 21' 4" the bulk of it with 4-m. and 4.50-m (13' 1 1/2" and 13' 9") wheelbases;

(d) engines and tenders with 3.20-m to 4.50-m. (10' 6" to 13' 9") rigid whee base.

The minimum radius of the curves = 300 m. (984') and Haarmann's formula

$$w_r = 600/(R-50) \quad . \quad . \quad . \quad ($$

given in Table III as No. 3, is used calculate w_r.

According to this formula the maximum resistance due to the curves will $w_r = 2.40$ kgr./t. (5.38 lb. per Engl. ton for all the stock indiscriminately, a regardless of the weather.

If more thought had been given to t subject, the formulæ of Table II cou have been used, corresponding to t wheelbase of each class of stock and coefficients of friction f taken as 2 kgr./t. (537.6 lb. per Engl. ton) for su mer working, and 165 kgr./t. (369 lb. p Engl. ton) for the winter. The resistan w_r would then have varied between 1 kgr./t. and 3 kgr./t. (3.29 and 6.72 per Engl. ton) for summer service a from 1.1 kgr./t. to 2.11 kgr./t. (2.46 4.73 lb. per Engl. ton) for winter servi taking into account the extreme whe bases of 2 m. and 6.50 m. (6' 6 3/4" a 21' 4").

Formula No. 3 only applies to an ave-ge wheelbase $s = 4.72$ m. (15' 6") as ll be seen easily by the following ap-cation of the formula *(a)* we are about suggest.

The objection of complication due to multiplicity of formulæ is not justi-d, as, to begin with, there is nothing prevent their number being reduced reasonable averages, and secondly in king such calculations an endeavour made to keep as close to the actual ts as possible.

For a long time we have stressed the portance of not using any resistance motion formulæ other than that due gravity, unless the conditions and li-mits they represent are known fully. As a matter of fact, we have found many times, when going through the figures of the same experimental measurements, that various formulæ could be used to interpret them, without it being permitted, however, to extrapolate nor to interpret these formulæ rigidly; *in most cases they have a meaning when used as a whole but not as regards their separate terms.* Scientific mechanics alone give single formulæ for representing the facts, yet without the right of indefinite extrapolation.

A classical example is given by the experimental formulæ of the French Nord Railway :

$w_g = 1.45 + 8 \quad (0.01\ V)^2$ . . . . . for open wagons;
$w_g = 1.60 + 2.30 \quad (0.01\ V) + 4.6 \quad (0.01\ V)^2$. for 4-wheeled coaches;
$w_g = 1.60 + 0.456 \quad (0.01\ V) + 4.56 \quad (0.01\ V)^2$. for bogie coaches,

ich are rightly considered as very accurate.

These formulæ can very well be replaced by the following :

$= 7\ (0.01)\ V$
$= 2.50 + 6\ (0.01\ V)^2$
$= 2.20 + 4.44\ (0.01\ V)^2$

} but only under the conditions and within the limits of speed, number and weight of each vehicle, type of stock, method of lubrication, etc... they represent.

The same ideas apply, *a fortiori,* to the mulæ used to calculate w_r. Many for-læ are available for this calculation, there are few indications as to the iting conditions of the application; s involves reference to the original ers, which is not always convenient. n the case of curves, the indications usually restricted to the track gauge, without it being shown in the formu-in some rare instances the gauge e and distance between centres s are incor-ated in the indications. Other factors ectly affecting the resistance to the ent of doubling it are not shown ex-citely. The results of the calculations if based on an ill-selected formula, are incorrect; the Paris Metropolitan coaches carried on 2.25 m. (7' 4 19/32) wheelbase bogies run over standard-gauge curves of 50 m. (164') radius at 25 km. (15.5 miles) an hour; formulæ Nos. 1 and 3 of Table III would give these coaches a negative or infinite curve resistance. GOERING's formula No. 2 would give a resistance of 25 kgr./t. (56 lb. per Engl. ton), whereas it is only 9.26 kgr./t. (20.74 lb. per Engl. ton) in summer and 6.94 kgr./t. (15.54 lb. per Engl. ton) in winter, according to the formulæ corresponding to the distance between centres of 2.25 m. (6' 10 1/2") in Table II.

B. — Formula we suggest be used in preference to all others.

In all the formulæ given below the following notations are used :

w_r = the resistance in kgr./t. of the gross weight of a vehicle or of a *whole* train per metre run, i.e. the specific or unit resistance on curves;

w'_r and w''_r = as above, but for the engine and tender or for the train *hauled* (excluding engine and tender);

f and f_v = the coefficients of friction, in kgr., between the tyres and the rails at low speed and at a speed of V km./h., per metric ton of train weight;

e = the track gauge, in metres, between the centre lines of the rails (e = 1.50, 1.06, 0.8 or 0.65 m. (4' 11", 3' 5 3/4", 2' 7 1/2" or 2' 1 5/8") for the most widely used gauges : 1.435 m., 1.00 m., 0.75 m. and 0.60 m. (4' 8 1/2", 3' 3 3/8", 2' 5 1/2" and 1' 11 5/8");

e' = the distance in metres between the axle guards of one pair of wheels (e' = 1.75 m., 1.30 m., 1.00 m. and 0.85 m. (5' 9", 4' 3 13/64", 3' 3 3/8" and 2' 9 1/2") for the above gauges);

s = the rigid wheelbase or distance, in metres, between centres of the axles of the outer pairs of wheels under the common underframe (the case of the coupled wheels of articulated locomotives);

R = the axial radius, in metres, of the curve, the resistance w_r of which is required;

R' = the most usual minimum radius, in metres, of curves, on the sections of line, to which the wheelbase s has to be related);

R" = the minimum radius, in m tres, of the curves on which vehicle with a wheelbase s is be inscribed but over which could not run;

r and m = the mean radius of the whe at the tread and the height their flanges, in metres;

J = the total play of the track curves (play on the straight a gauge widening on curves, any), in metres;

J' = the average play between axle-guards and axle-boxes, ken in the *orthogonal* position the axles, in metres.

We give, in Table III, using the ab notation, all the curve resistance form læ known to us.

Except as regards North America, think the formulæ most used are nu bers 1, 2, 3, 9 and 11 the formulæ un No. 7 being used chiefly in America bogie stock.

All these formulæ for the same ga and radius of curve are far from giv the same specific resistance. For exa ple, formulæ No. 1 give the same val as formulæ No. 11 for radii of 41 100, 150 and 15 m. (1333', 328', 492' a 49' 2") only, for standard, metre and cm. (1' 11 5/8") gauge lines. Be these radii, formulæ No. 1 give grea resistance values than No. 11, and ab these values, the opposite takes place.

The differences between the res are considerable :

for R = 100 m. and e = 0.65 m. we g

w_r = 2.11 by formula No. 1 and

w_r = 3.22 by formula No. 11, or 54 % more.

Table IV has been prepared to sh more clearly the differences between

lts obtained from formulæ No. 1, and DOUITS' formula, No. 11.

n exceptional cases of small radii, (see mples in *Chemins de fer*, page 28, by ASSEUR), relatively to the track gau- such as is the case with many tram- s or underground lines either stan- l gauge or not), the differences are n more marked, as we saw above he case of the Paris Metropolitan.

he above anomalies have led us for a ; time to insist on the use of the for- a *(a)* :

$$w_r = 0\ 50\ f\ (e + \sqrt{e^2 + s^2})/R. \quad (a)$$

ch formula has been confirmed nost treatises on railway practice (see particular the works by DEHARME-PU- VICAIRE-MAISON, OTTONE, CORINI, PA- -TÉTREL...).

We will confine ourselves to noting this formula is primarily built up n the sum of the resistances due to itudinal ($0.50\ fe/R$) and transverse $0\ f\sqrt{e^2+s^2}/R$) sliding friction of tyres on the rails, and ignores the ny other factors which can influence greater or lesser extent the value of resistance w_r, such as : the regular ut of the curve, excessive striking an- gauge widening in curves, excess or in superelevation, number of pairs wheels, ability of the wheels to set nselves to the curves (convergence ards the centre of the curve, or lon- dinal displacement), length of the n and its position on the curve, coupl- more or less tight, unit tractive ef- , running speed, and in particular the effect of the tyre contour relatively to that of the rails.

It should be noted, however, that in COUCHE's well known treatise on railways (Vol. III, p. 649) the following formula is found :

$$w_r = 0.50\ f\ (e + s)/R\ .\ .\ (10)$$

It is given under No. 10, in Table III, and based on arguments similar to those admitted when making out formula *(a)*, but less rigid. This formula, better known as REDTEMBACHER's, gives lower resistance values than formula *(a)*.

Two similar formulæ are given in HENSCHEL's *Locomotive Engineer's Handbook*, 1935 edition, page 48, and are given under No. 13 in Table III. These formulæ do not explicitely take into account the friction coefficient f.

Similarly formulæ Nos. 8 and 9 of Table III take the wheelbase s into account, but are given for standard gauge only, and again do not include explicitely the friction coefficient f.

It is really astonishing that formula *(a)* has not come into general use so far. The only reason we can suggest is the root sign it includes, although this may be eliminated easily in several ways.

With this object in view, we have compiled Table I, which gives the exact values of the factor

$$\alpha = 0.50\ (e + \sqrt{e^2 + s^2})$$

in formula *(a)*, which factor we will call *the modulus of resistance on a curve of radius R* for a gauge e and a rigid wheelbase s.

Table I has been calculated for the following limits of the wheelbase s :

75 to 8.25 m. (5' 9" to 27' 1")	for standard gauge . . . . . (e = 1.50 m.).
25 to 5.00 m. (4' 1 1/4" to 16' 5")	for metre gauge . . . . . (e = 1.06 m.).
00 to 3.00 m. (3' 3 3/8" to 9' 10 1/8")	for 0.75 m. (2' 5 1/2" gauge) . (e = 0.80 m.).
00 to 2.50 m. (2' 11 1/2" to 8' 2 15/32")	for 0.60 m. (1' 11 5/8" gauge) . (e = 0.65 m.).

The results in each vertical column of this table can be calculated with close approximation, by a linear expression,

$$\left.\begin{aligned} w_r &= f\ (1.060 + 0.470\ s)/R \\ w &= f\ (0.726 + 0.473\ s)/R \\ w_r &= f\ (0.584 + 0.456\ s)/R \\ w_r &= f\ (0.467 + 0.460\ s)/R \end{aligned}\right\} \quad (b)$$

for standard-gauge track,
for metre gauge,
for 0.75 m. (2' 5 1/2") gauge,
for 0.60 m. (1' 11 5/8") gauge.

from which the following formulæ f the resistance w_r can be made out :

Seeing how the coefficient f varies with the atmospheric conditions and the multitude of other factors which more or less come into the question, the following general formula (12) can be suggested in place of formula *(b)*

$$w_r = f\,(0.72\,e + 0.47\,s)/R \quad . \quad (12)$$

shown under No. 12 in Table III and applicable in all cases within the limits of the wheelbase s values given above.

Values to be used for the friction coefficient *f*.

When using the general formula *(a)* or those derived therefrom, *(b)* or 12, it is important to fix a value for the friction coefficient f.

This coefficient varies not only with the condition of the rails and tyres, i. e. with the atmospheric conditions, but also with the running speed (see PARODI-TÉTREL, *La Traction électrique*, Vol. I, page 311). The following limiting values are assigned to it :

330 kgr./t. (739 lb. per Engl. ton) for very dry or clean tyres and rails (very hot weather or after heavy rain);

100 kgr./t. (224 lb. per Engl. ton) for greasy, damp or dirty rails or tyres;

220 kgr./t. (493 lb. per Engl. ton) as an average value at low speeds.

At a speed V km. an hour, we get

$$f_v = 220/(1 + 0.01\,V) \quad . \quad . \quad (c)$$

In the case under consideration, af many investigations into the matter, have adopted the following average valu of f :

220 kgr./t. (493 lb. per Engl. ton) for summer working
165 kgr /t. (370 lb per Engl. ton) for winter working
} in temper climates

We will not take into account any ductions in the values of f due to incr ses in the speed V, as given by eq tion *(c)*. A train might stop or sl down to a very low speed on a curve; these two cases f will have a greater lue than *after* V has decreased, and c sequently the resistance w_r will then greater.

In a very detailed report *(Bulle of the Railway Congress Associati* August, 1892, p. 2407, French editio Messrs. LANCRENON and MORANDIÈRE br out in several places (pp. 2429, 24 2499, 2508...) the capital importance the wide variation of the resistance according to the atmospheric conditio a fact with which the locomotive runn and permanent way staff are very con sant. This explains why the bad weat season, as regards the state of the rails tyres, and the high speeds as rega the reduction of f with the increase the speed V, make it easier to run thro curves; the opposite occurs in hot rainy weather, and at low speeds. To s up, when the friction coefficient f is

laced by its average value of 220 kgr./t. for summer working, and by 165 kgr./t. or winter working, the formulæ can be written :

$$\left.\begin{aligned} w_r &= (233.20 + 103.40\ s)/R \\ w_r &= (159.72 + 104.06\ s)/R \\ w_r &= (128.48 + 100.32\ s)/R \\ w_r &= (102.74 + 101.20\ s)/R \end{aligned}\right\} \quad (d)$$

for standard-gauge track,
for metre gauge,
for 0.75 m. gauge,
for 0.60 m. gauge.

or summer working, and

$$\left.\begin{aligned} w_r &= (174.90 + 77.55\ s)/R \\ w_r &= (119.79 + 78.05\ s)/R \\ w_r &= (96.36 + 75.24\ s)/R \\ w_r &= (77.06 + 75.90\ s)/R \end{aligned}\right\} \quad (d')$$

for standard-gauge track,
for metre gauge,
for 0.75 m. gauge,
for 0.60 m. gauge.

r winter working.

Formula No. 12 will become :

$w_r = (158\ 40\ e + 103.40\ s/R...(e)$ for summer working, and
$w_r = (118.80\ e + 77.55\ s/R..\ (e')$ for winter working.

Comparison with formula No. 13.

Making $e = 1.50$, 1.06, 0.80 and 0.65 (4' 11", 3' 5 3/4", 2' 7 1/2" and 2' 1 5/8") in formula No. 13, we get the following resistance formulæ for the main lines :

$$\left.\begin{aligned} w_r &= (99.00 + 140\ s)/R \\ w_r &= (69.96 + 140\ s)/R \\ w_r &= (52.80 + 140\ s)/R \\ w_r &= (42.90 + 140\ s)/R \end{aligned}\right\} \quad (13')$$

for standard-gauge track,
for metre gauge,
for 0.75 m. gauge,
for 0.60 m. gauge.

These formulæ give the same resistance values as formulæ *(d)* for wheelbases of :

$s = 3.78$ m. (12' 5") for standard-gauge track,
$s = 2.68$ m. (8' 9 1/2") for metre gauge,
$s = 2.02$ m. (6' 6 53/64") for 0.75 m. gauge,
$s = 1.64$ m. (5' 4 9/16") for 0.60 m. gauge.

For longer wheelbases the resistances tained are higher than those obtained om our formulæ *(d)*; for shorter eelbases, the opposite occurs. In any e, the differences are not appreciable; example, with a long wheelbase $s =$ 0 m. (21' 4") the first formula (13') es : $w_r = 1009/R$, and the corres-nding formula *(d)*..... : $w_r = 905/R$, 11.5 % less.

C. — Conclusion.

We suggest the following general formula for calculating the specific resistance w_r for a track *of any gauge e*, a rigid wheelbase s an a friction coefficient f, to be fixed according to the climate and the time of the year

$$w_r = 0.50\ f\ (e + \sqrt{e^2 + s^2})/R... \quad (a)$$

even for *broad-gauge lines.*

For standard, metric, 0.75-m.(2' 5 1/2") and 0.60-m. (1' 11 5/8") gauges we suggest :

1. the use of the moduli of resistance on curves of Table I, multiplied by the factor f/R in order to obtain the formula of the curve resistance, the value of f having to be fixed to suit the climatic conditions;

2. the use of formulæ *(b)*, the coefficient f being determined as in case 1;

3. the use of formulæ *(d)*, *(d')*, *(e)* and *(e')*, with $f = 220$ kgr./t. (493 lb. per Engl. ton) in summer and 165 kgr./t. (370 lb. per Engl. ton) in winter;

$s = 4.96$ m. (16' 3 9/32") for standard-gauge track,
$s = 3.50$ m. (11' 5 25/32") for metre gauge,
$s = 2.65$ m. (8' 8 23/64") for 0.75 m. gauge,
$s = 2.25$ m. (7' 4 19/32") for 0.60 m. gauge.

which is not necessarily so.

For higher or lower values of s than those given above, the formulæ *(e)* give larger or smaller values than those obtained when DESDOUITS' formula No. 11 is used.

The discordances of the calculated results are not due to the general formula *(a)*, nor to those derived from it *(b)*, *(d)*, *(d')*, *(e)*, *(e')*; they are due to the compared formulæ not having been made out to be applied in all cases.

We are aware that in Messrs. LANCRENON and MORANDIÈRE's excellent report mentioned earlier, it is held that the wheelbase s has no appreciable influence on the increase or reduction in the resistance w_r because from the experimental measurements made, especially those of DESDOUITS, no differences in curve resistance were observed on vehicles having wheelbases of 2.50 m. = 8' 2 7/16" (short wagons) to 5.40 m. = 17' 8 19/32" (large passenger coaches).

4. the use of the resistance formul of Table II, based on the exact formu *(a)*, with $f = 220$ kgr./t.. in summer ar 165 kgr./t. in winter.

The results obtained when using the formulæ will not agree in all cases wi those obtained from the many existi formulæ. For example, if DESDOUITS' g neral formula

$$w_r = 500\, e/R \quad . \quad . \quad . \quad (1$$

is to give the same results as our fo mula

$$w_r = (158.40\, e + 103.40\, s)/R \ldots\ldots \quad (4$$

s must always equal $3.30e$, i. e.

Mr. LANCRENON was even more positi on the subject (page 2432) when he sta ed that « bogie vehicles do not show e cess resistances lower than those of oth vehicles and, in fact if the bogie vehic wheelbase were made too small, the r sistances might be greater... ». The sam point of view is upheld on page 2503 the said report, whereon wheelbases 3.50 to 5.90 m. (11' 6" to 19' 4 9/32" are mentioned.

We must admit nonetheless that t bogie makes the running of the vehicl much easier even in the case of curv of small radius, this being confirm since its introduction in America, by fo mulæ No. 7. of Table III, which gi much lower resistances than formulæ n explicitely taking into account the whe base s. These formulæ Nos. 7 agr with formula *(a)* or its derivatives f the ordinary wheelbases of standard gau bogies [$s = 2.00$ to 3.60 m. (6' 6 3/4" 11' 9 23/64")].

— Restriction to the application of urve resistance formulæ for radii xceeding R" and R'.

. *Minimum radius R".* — Curve re-ance formulæ of the form $w_r = (R-b)$ . . . *(f)* wherein *a* and b are stants relatively to R, mean that when radius R approaches the value of the stant *b*, the resistance w_r increases rmously, until it becomes infinite en R = R" = *b*. The result is that value R" = *b* gives the limit curve ich a vehicle with a wheelbase *s* can otiate, this wheelbase *s* being that d when establishing the formulæ *(f)*, without being able to run through it is *imprisoned* or *wedged* in the ve.

Thus, for all radii R less than, equal or but little different from *b*, the mulæ *(f)* cannot be applied; they give ative, infinite or exaggerated results. The limiting unequalities (see COUCHE, 1, page 241) :

$(JR''-2rm)/\sqrt{2rm}$

4-wheeled vehicles,

$\sqrt{8R''J} - 2\sqrt{2rm}$ for 6-wheeled icles :

nect the maximum wheelbase *s* with minimum radius R" for the case of limiting curve; if we take *s* = 5.00 (16' 5"), J = 0.040 m. (1 37/64"), = 1 m. (3' 3 3/8"), and *m* = 0.030 m. 3/16"), we get in the case of the heeled vehicles :

$\geqslant (s\sqrt{2rm} + 2rm)/J = 69.21$ m. (228'),

l in the case of 6 wheeled vehicles :

$= \geqslant [s + 2\sqrt{2rm}]^2, 8J = 112.73$ m. 0')

n the same way, the formulæ of the m $w_r = a/R$ . . . should not be ap-ed in the case of values of R equal to, than, or little different from R"; y give exaggerated results. DESDOUITS' formula $w_r = 750/R$ applied to the Paris Metropolitan (R = 50 m. = 164') gives a resistance $w_r = 15$ kgr./t. (33.6 lb. per Engl. ton) whereas actually $w_r = 463/R = 9.26$ kgr./t. (20.74 lb. per Engl. ton) or 62 % less.

2. *Minimum radius R'.* — Besides this radius R", it may be queried what is the most frequently met minimum radius R', *properly coordinated with a pre-selected wheelbase s.*

Based on the diagonal inscription of the vehicles in curves, and the practice of the German Railway Union, we got out a long time ago the equations :

$s = 0.30\sqrt{R'}$.... *(g)* for carriages and wagons, and

$s = 0.24\sqrt{R'}$.. . *(h)* for locomotives, giving the relationship between the wheelbase *s* of the vehicles and the minimum radius R' most frequently encountered on a particular section of line, for safe running and proper use of the rolling stock and track.

The running would still be safe when $s = 0.34\sqrt{R'}$ for the rolling stock, and even $s = 0.35\sqrt{R'}$ is admitted.

From the above equations we deduce the values of the radii R', well suited to the pre-selected wheelbases *s*, and we obtain :

$R' \geqslant 11.11s^2$ for carriages and wagons,

$R' \geqslant 17.35s^2$ for locomotives.

Consequently on a given section of track well suited to the stock having a wheelbase of 5 m. (16' 5"), the radii R' should not be less than $11.11 \times 5^2 = 278$ m. (912') nor should there be locomotives with a rigid wheelbase exceeding 4 m. (13' 1 1/2").

We could also use the classic expression

$$J' \leqslant se'/4R'. \quad . \quad . \quad . \quad (i)$$

which relates the play J' to the other factors, s, e' and R'.

This maximum play J' usually is less than 0.01 m. (13/32") for low speeds, and 0.005 to 0.007 m. (13/64 to 9/32") for high speeds.

From expression *(i)* we get :

$$R' \geqslant se'/4J'. \quad . \quad . \quad . \quad (k)$$

Taking $e' = 1.75$ m., 1.30 m, 1 m. and 0.85 m. (5' 9", 4' 3 13/64", 3' 3 3/8" and 2' 9 1/2") for the standard, metre, 0.75 m. and 0.60 m. gauges with a play J' of 6, 7, 8 and 9 mm. (15/64", 9/32", 5/1 and 23/64") respectively, we get fro expression *(k)*

R' $\geqslant$ 73 s for standard-gauge track,
R' $\geqslant$ 46.5 s for metre gauge,
R' $\geqslant$ 31 s for 0.75 m. gauge,
R' $\geqslant$ 23.6 s for 0.60 m. gauge.

For minimum wheelbases of 2.00 1.50 m., 1.25 m. and 0.90 m. (6' 6 3/ 4' 11", 4' 1 13/64" and 2' 11 1/2") the above gauges we get :

R' $\geqslant$ 146 m. (479') for standard-gauge track,
R' $\geqslant$ 69 m. (226') for metre gauge,
R' $\geqslant$ 39 m. (128') for 0.75 m. gauge,
R' $\geqslant$ 21 m. (69') for 0.60 m. gauge.

Curves of smaller radii should not be used when laying out railways.

E. — Is the specific resistance w'_r of locomotives and tenders the same as that w''_r of wagons and carriages ?

Formulæ Nos. 9 of Table III are the only ones giving, for standard gauge lines, the specific resistance of carriages, wagons, and locomotives separately.

The wheelbase s is brought into account in the first two formulæ, the value being 1 000/R for carriages, and 2 000/R for wagons. The third formula ignores the wheelbase s; moreover it is the same as that given by formulæ No. 1 for standard gauge and for the whole train.

If R be taken as 300 m. (984') on standard gauge lines, it will be appreciated that when $s = 4.85$ m. (15' 11") the formula for carriage resistance will give the same values as FRANCK's formula for locomotives; when $s > 4.85$ m. the formula for carriages will give higher values than that applicable to locomotives, and when $s < 4.85$ m., the formula for locomotives will give higher values than that applicable to carriages.

Our formula No. 12 was based on single vehicle, whether locomotive, te der, wagon, or carriage, provided t wheelbase be s and the gauge e. To c tain the total train resistance it is suf cient to add together the relative res tances of all the vehicles and, if nec sary, abstracting therefrom the res tance value w'.

In practice an average wheelbase s used for the whole train, and the avera resistance w_r is calculated therefrom a applied to the tonnage of the whole the train.

When the question is considered m in detail, we must admit that the speci resistance of the engine or tender greater than that of a carriage or wag of the same wheelbase s; this is due only to their position at the head of train (greater guiding forces, differ ces in the direction of the tractive eff etc.) but mainly to the closer solida of the wheels and axles with their derframes (vertical spring links, lack clearance between axle boxes and hor etc.), the whole still being aggravated a larger number of pairs of wheels b

upled and carrying, which are more eavily loaded.

DESDOUIT's experiments (see *Bulletin of e Railway Congress*, August 1892, French edition, pp. 2436-2442) on standard gauge 100-m. (328') radius curves gave the following values of the resistance w_r :

1. Single carriages or wagons . . 8 to 6 kgr./t. (17.9 to 13.4 lb. per Engl. ton),
2. Engines with their tenders . 9 to 8 kgr./t. (19.2 to 17.9 lb. per Engl. ton),
3. Whole trains . . . . . 7 kgr./t. (15.7 lb. per Engl. ton).

These figures indicate an average re- stance w_r'' on a 100-m. (328') radius rve for single carriages and wagons ual to that w_r of the whole train, whilst e resistance w_r' of the engine and ten- r is 14 to 28.5 % higher than that of e whole train.

In any case, if L be the average weight the locomotive and tender in metric ns and Q that of the train hauled, we ways have the relation :

$$L \cdot w_r' + Q w_r'' = (L + Q)\, w_r$$

om which we can find one of the spe- fic resistances when the other two are own.

The 14 % difference for the locomo- es, referred to above, will undoubtedly minish as the radius R increases above 0 m. (328'), so that in practice no dis- nction need be made as between the en- nes, and tenders, carriages and wagons, ovided that for equal wheelbases s, the me specific resistance

$$w_r = w_r' = w_r''$$

attributed to them.

F. — Curve radii of equivalent esistance for different track gauges.

Using DESDOUITS' formula No. 11

$$w_r = 500e/R \quad . \quad . \quad . \quad (11)$$

is admitted that for an equal radius R a layout, the reduction of the resis- nce w_r be taken as proportional to the luction of the gauge e, and that con- quently the radius of the sharpest curve can be reduced in the same proportion. Thus it has been stated that the resistance on a standard gauge curve of 300 m. (984') radius is the same as that of a 200-m. (656') curve on metre gauge, of a 150-m. (492') curve on 0.75 m. (2' 5 1/2") gauge, and of a 120-m. (393') curve on 0.60-m. (1' 11 5/8") gauge track.

These statements exaggerate the influence of the gauge e on the resistance w_r, as a glance at the resistance moduli of Table I or at the corresponding values of Table II will show.

Let us take the case of a wheelbase s = 3.50 m. (22' 11 5/8") on standard and metre gauges. According to Table II, the resistance formulæ are the following:

standard gauge, $w_r = 584/R$
metre gauge, $w_r = 519/R$
} in summer

If the formulæ are to give the same resistance, we must have

$$R_1 = R\,\frac{519}{584} = 0.89\,R \text{ approx.}$$

If we take R = 300 m. (984') for the standard gauge the radius of equivalent resistance would be R = 0.89 × 300 = 267 m. (876') and not 200 m. (656') as is often claimed.

The reason for this large difference is that the wheelbase s is not taken into account in formulæ No. 11.

Likewise, for a 2.50-m. (8' 2 7/16") wheelbase s on metre gauge and 75-cm.

(2' 5 1/2") gauge, the resistance formulæ would be :

metre gauge, $w_r = 416/R$
0.75 m. gauge, $w_r = 377/R_1$ } in summer

$$R_1 = R \times \frac{277}{416} = 0.906 \times R,$$

and when R = 150 m. (492') on metre gauge the 75-cm. (2' 5 1/2") gauge curve of equal resistance will be $R_1 = 0.906 \times 150 = 136$ m. (446') and not 112.5 m. (369') as given by DESDOUITS' formula. For a 1.75-m. (5' 9") wheelbase on 0.75 and 0.60-m. (2' 5 1/2" and 1' 11 5/8") gauge tracks, the resistance formulæ would be :

0.75 m. track, $w_r = 300/R$
0.60 m. track, $w_r = 277/R_1$ } in summer

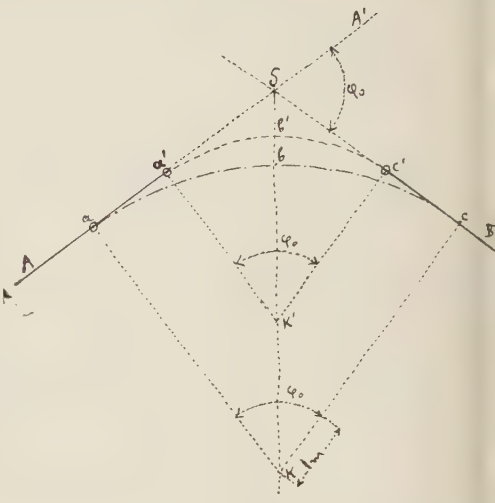
$$R_1 = R \times \frac{277}{300} = 0.923\ R$$

and when R = 75 m. (246' 3/4") on 0.75-m. track, $R_1 = 69$ m. (226' 4 5/8") and not 60 m. (196' 10") as given by formulæ No. 11.

G. — **The total resisting work during the passage over a curve of radius R is independent of this radius; it is simply proportional to the angle made by one of the tangents relatively to that made by the preceding one.**

To conclude this article, we think the following points should be stressed : It is frequently stated, and written, that the radii of curves should be increased to reduce their resistance. This is untrue, if it is not stated that specific resistance w_r, i. e. the resisting work per metre travelled and per ton of weight, is in question.

As a matter of fact, the total resisting



work due tot the transverse and longitudinal slip of the tyres on the rails is

$$T_r = Pf\ \varphi_0 \sqrt{e^2 + s^2}/2 + Pf.e\ \varphi_0/$$
$$T_r = 0.50\ Pf\ \varphi_0\ (e + \sqrt{e^2 + s^2}),$$

in which φ_0 is the angle at the centr *akc*, or A'SB, of any curve *abc* over whic the train has passed to get from th straight section ASA' to the followin one, ScB.

The large radii K*a* are required, not t diminish the work T_r, but simply to ove come it over a longer distance *abc* i stead of *a'b'c'* which would give a sma ler radius K'*a'*; furthermore, to redu the length of track which increases the radius K*a* becomes smaller; and f nally to reduce the maintenance costs, allow for higher speeds. to provide bett visibility, etc.

Briefly the specific resistance

$$w_r = 0.50\ Pf\ \varphi_0\ (e + \sqrt{e^2 + s^2})/PR$$
$$= 0.50\ f\ (e + \sqrt{e^2 + s^2})/R$$

alone varies inversely as the radius and not the total work T_r which is ind pendent of R and varies directly as t angle A'SB = φ_0.

TABLE I.

Moduli of resistance on curves :

$$\alpha = 0.5\ (e + \sqrt{e^2 + s^2})$$

Wheelbase s =	Standard gauge α =	Metre gauge. α =	0.75-m. gauge α =	0.60-m. gauge α =
0.90				0.8810
1 00			1.0403	0.9214
1.25		1.3495	1.1415	1.0295
1.50		1.4350	1.2500	1.1424
1.75	1.9024	1.5530	1.3620	1.2584
2.00	2.0000	1 6465	1.4770	1.3765
2 25	2.1020	1.7735	1.5940	1.4960
2.50	2.2077	1.8875	1.7125	1.6165
2.75	2.3161	2.0035	1.8320	
3.00	2.4270	2.1210	1.9525	
3.25	2.5400	2.2390		
3.50	2.6539	2.3580		
3.75	2.7690	2 4785		
4.00	2 8860	2.5990		
4.25	3.0030	2.7200		
4.50	3.1215	2.8415		
4.75	3.2405	2.9635		
5.00	3.3545	3.0895		
5.25	3 4800			
5.50	3.6000			
5.75	3.7180			
6.00	3.8400			
6.25	3.9635			
6.50	4.0855			
6.75	4.2070			
7.00	4.3295			
7.25	4.4500			
7.50	4.5740			
7.75	4.7000			
8 00	4.8190			
8.25	4.9400			

Use of the constants : To find the resistance formula for vehicles of wheelbase $s = 2.50$ m. on standard and metre-gauge track.

Answer : The formulæ required are :

$w_r = 2.2077\ f/R$ for standard gauge,
$w_r = 1.8875\ f/R$ for metre gauge.

Taking $f = 220$ kgr./t. in summer and $3/4\ f = 165$ kgr./t. in winter,

we obtain :

(a) Standard gauge :

$w_r = 486/R$ for summer service;
$w_r = 365/R$ for winter service.

(b) Metre gauge :

$w_r = 416/R$ for summer service;
$w_r = 312/R$ for winter service.

TABLE II.

Numerators for the general resistance formula : $w_r = 0.50\, f\left(e + \sqrt{e^2 + s^2}\right)/R$

Wheelbase s =	Standard gauge		Metre gauge.		0.75-m. gauge		0.60-m. gauge	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winte
0.90							194	146
1.00					229	172	203	152
1.25			297	223	252	189	227	170
1.50			316	237	275	207	252	189
1.75	419	314	342	257	300	225	277	208
2.00	440	330	363	272	325	244	303	228
2.25	463	347	391	293	351	263	330	247
2 50	486	365	416	312	377	283	356	267
2.75	510	382	441	331	403	303		
3.00	534	401	467	350	430	323		
3.25	559	420	493	370				
3.50	584	438	519	389				
3.75	610	457	546	409				
4.00	635	477	572	429				
4.25	661	496	599	449				
4.50	687	515	626	469				
4.75	713	535	652	489				
5.00	738	554	680	510				
5 25	766	575						
5.50	792	594						
5.75	818	614						
6.00	845	634						
6.25	872	654						
6.50	899	675						
6.75	926	695						
7.00	953	715						
7.25	979	735						
7.50	1 007	755						
7.75	1 034	776						
8.00	1 061	796						
8.25	1 087	815						

Example of the use of the table

For vehicles of wheelbase s = 2.50 m., the resistance formulae in summer will be :

w_r = 486/R for standard gauge;
w_r = 416/R for metre gauge;
w_r = 377/R for 0.75-m. gauge;
w_r = 350/R for 0.60-m. gauge.

The numbers in the vertical columns are the numerators in the general formula

$$w_r = 0.50\, f\left(e + \sqrt{e^2 + s^2}\right)/R$$

in which the following values have been assumed :

f = 220 kgr./t. in summer service;
f = 165 kgr./t. in winter service;
e = gauge, from centre to centre of rails, in metres;
s = rigid wheelbase, in metres;
R = axial radius in metres;
w_r = specific resistance in kgr./t.

TABLE III.

Formulæ for calculating the special unit resistance due to curves.

Formulæ.	No.	e = 1.50 m.	1.06 m.	0.80 m.	0.65 m.
erman	1	650/(R-55)	400/(R-20)	350/(R-10)	200/(R-5)
oering	2	500/(R-30)	400/(R-20)	350/(R-10)	200/(R-5)
aarman	3	600/(R-50)	400/(R-25)	350/(R-10)	200/(R-5)
zygan.	4	...	...	500/(R-6)	...
talian State Rys. . .	5	800/R	...	...	...
Veitzner	6	(800-0.4 R)/(R-40)	...	...	...
Jorth America	7	(525 to 700)/R	Some years ago.		
		(446 to 472)/R	Quite recently.		
on Hoffmann	8	$21\ (4s + s^2)/(R-5)$	Rigid axles.		
		$40\ s/R + 0.40$	Radial axles.		
lb. Frank	9	$\frac{s}{R}\left(180 \cdot 1\ 000 \frac{s}{R}\right)$	For carriages.		
		$\frac{s}{R}\left(180 \cdot 2\ 000 \frac{s}{R}\right)$	For wagons.		
		650/(R-55)	For locomotives.		
edtembacher	10	$< \ldots w_r = 0.50\ f\ (e + s)/R$			
ouche.					
esdouits	11	$< \ldots w_r = 500e/R$			
roposed by the author :	12	$< \ldots w_r = f\ (0.72e + 0.47s)/R$			
Jenschel Locomotive Pocket Book (p. 48) :	13	$w_r = (66e + 140s)/R$ for the main lines			
		$w_r = (50e + 110s)/R$ for the secondary lines			

Works from which the above formulæ were taken :

No. 1 : *Hütte*, 26th German edition, vol. III, p. 875;

No. 9 : *Hütte*, 25th German edition, vol. III, p. 739;

Nos, 2, 3, 4 and 8 : *Enzyklopädie des Eisenbahnwesens*, by V. RÖLL, vol. 8, p. 353.

Nos. 5, 6 and 7 : *La traction électrique*, by H. PARODI and A. TETREL.

TABLE IV.

Comparative values of the curve resistances according to formulæ Nos. 1 and 11 of Table III.

1. According to formulæ No. 1.

Radius, m.	650/(R—55)	400/(R—20)	350/(R—10)	200/(R—5)
25				10.0000
45			10.0000	5.0000
60		10.0000	7.0000	3.6363
120	10.0000	4.0000	3.1818	1.7391
150	6.8421	3.0769	2.5000	1.3793
200	4.4827	2.2222	1.8121	1.0256
250	3.3333	1.7391	1.4583	
300	2.6530	1.4286	1.2069	
350	2.2034	1.2121	1.0294	
400	1.8840	1.0526		
500	1.4606			
700	1.0077			

2. According to formulæ No. 11.

Radius, m.	750/R	500/R	375/R	300/R
30				10.0000
37.5			10.0000	8.0000
50		10.0000	7.5000	6.0000
75	10.0000	6.6667	5.0000	4.0000
120	6.2500	4.1667	3.1250	2.5000
150	5.0000	3.3333	2.5000	2.0000
200	3.7500	2.5000	1.8750	1.5000
250	3 0000	2.0000	1.5000	1.2000
300	2.5000	1.6667	1.2500	1.0000
350	2.1429	1.4286	1.0714	
400	1.8750	1.2500		
500	1.5000	1.0000		
600	1.2500			
700	1.0714			

625. 4]

n error to avoid in schemes for new underground lines,

by Th. MAKCHEEFF, Engineer.

A common failing in all existing un-rground lines is the inconvenience in-lved when changing trains. In Paris, example, the passengers are obliged change two or three times in many ses to get to their destination. Each ange means quite a walk through sub-ys and up and down stairs. Frequent-the changes take longer than the train rney. The new lines not provided in the original scheme have increased difficulty.

Let us endeavour to establish a gene-l principle for avoiding long walks rough passages and reducing the stair-ys to a minimum at connecting places. The streets of the large European cities all arranged as concentric circles con-cted by streets radiating from the cen-. This centre in Moscow is the Okhot--Riad, in Paris Le Châtelet, and in rlin the Friedrichstrasse. The succes-e rings of the boulevards form the cir-lar thoroughfares in the case of Paris in that of Moscow.

The frequency of the trains on the un-rground lines is too great to run trains different directions over the same cks. It is always possible, however, two lines to be arranged to cross one other at different levels when the ex-ange station is built as shown in the gram, figure 1.

With four lifts (A on this drawing) or irways the passengers only have to go or down once to change for any direc-n.

A circular station should be provided the centre of each city, with lines ra-diating from it in all directions as shown in figure 2. To change trains in this design of station the passengers have to walk round along the circulating area to the required platform.

These two methods of changing train are not tiring and compare more than

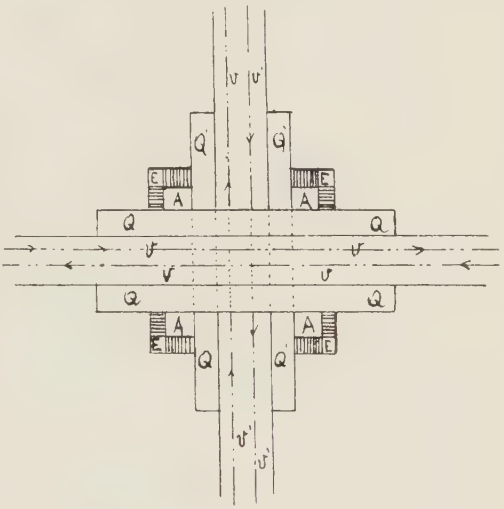


Fig. 1. — Exchange station for two crossing lines.

Explanation:

V Upper line.
V' Lower line.
Q Upper line platforms.
Q' Lower line platforms.
A Elevators.
E Stairways.

A change of train involves a single ascent or descent.

favourably with the long walks the Paris public has to take at the Concorde, Madeleine, Marbeuf and other stations.

In order to obtain only these two methods of connection and to reduce to a

minimum the number of changes between any two stations, it will be sufficient to lay out the metropolitan lines to the diagram, figure 3.

On such a system the passengers are brought to the centre of the city through trains, and can get from any or station to any other with only one chang of train. The number of changes is r duced to two in the most unfavourab

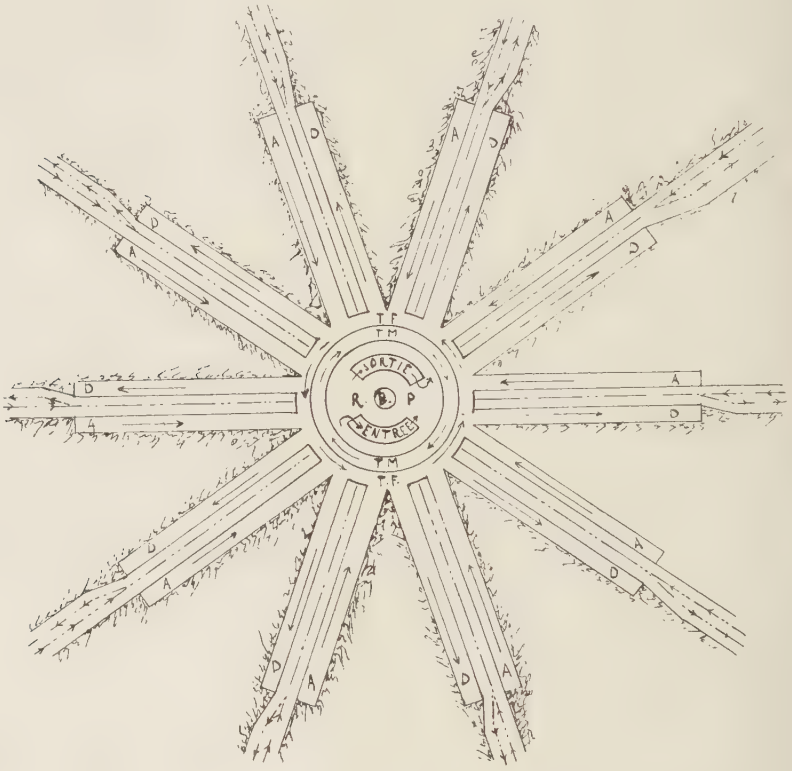


Fig. 2. — Central station wherein all the radial lines end.

Explanation:

A	Arrival platforms.	RP	Circulating area.
D	Departure platforms.	TF	Stationary foot walk.
B	Booking office.	TM	Moving foot walk.

The arrows show the direction the passengers walk.

cases, when it is desired to reduce the distance travelled. In Paris three changes are frequently necessary and the passengers have to follow a roundabout route to get to their destination.

The central station with its 10 or radial lines may be about 50 m. (164 in diameter. A revolving platform be provided at less cost than mov stairs and be arranged to revolve in

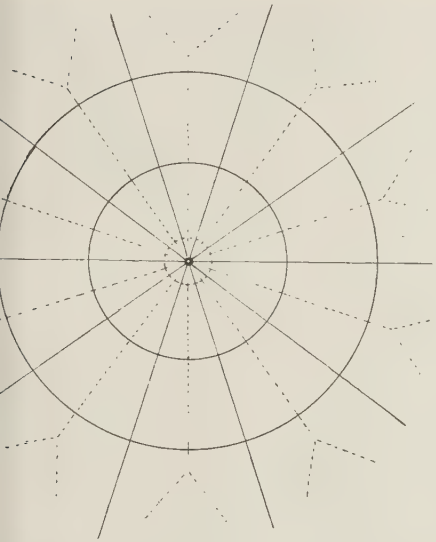


Fig. 3. — Theoretical diagram of the Metropolitan.

Explanation:

main system is shown by plain lines and the condary system by dotted lines. All radial lines id at the central circular station. All the secon- ary radial lines end in an exchange station with e inner ring line.

posite direction to that of the passen- s moving round the fixed circulating tform (see drawing, figure 4).

The stairways providing access to or m the central station can end directly the respective platforms. This arran- ment prevents the passengers entering leaving the underground station from shing with those simply changing ins (*).

In cities such as Berlin, where the new thods of transport in common were in- duced as technics progressed, the tropolitan was built when a dense net-

*) In the case of a city with the streets anged at right angles the metropolitan s should also be laid in the same way. this case only one change of train is need- as shown in figure 1.

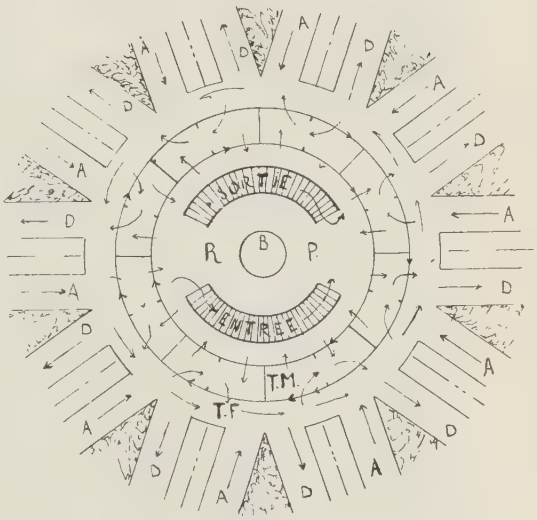


Fig. 4. — Circulating area with moving foot walk at the central station.

Explanation:

A Arrival platforms.
D Departure platforms.
B Booking office.
RP Circulating area.
TF Stationary foot walk.
TM Moving foot walk.

The arrows indicate the direction the passengers follow. The moving foot walk revolves in the opposite direction to that followed by the passengers on the fixed foot walk.

work of city railways and tramways was in existence. The various forms of public transport were then amalgamated and the metropolitan lines were laid to complete the existing city railways. By 1926 all the urban and suburban railways of Berlin were united into one organisation for the convenience of the passengers. Under these conditions the disadvantages of having to change trains were more than made up by the advantages of through tickets over all the lines.

When examining the layout of the Paris Metropolitan, which is entirely independent of any of the other public transport organisations, it will be seen that

Fig. 5. — Plan of Moscow. Scale : 1 in 100 000.

the system could have been arranged on the suggested principles quite easily whilst following almost all the existing lines. The central station would have been Le Châtelet, the present centre of the motorbus night services. It is too late to alter the Paris Metropolitan lines as suggested, but crossings of new li could be arranged as shown in figure

The plan of Moscow lends itself v to the arrangement of underground li shown in figure 3.

The central station would be Okhot Riad and all the radial lines shown

ıre 5 could terminate there. The in- ring line should follow the boule- ds and the Moskwa river, and the er ring the Sadowaya outer boule- ds.

t is therefore still possible to apply above principles to the Moscow Un- ground and so overcome in the future defects of the other European under- und lines. The supplementary expenditure on the exchange station should be provided for now, and the central station arranged so as to cut all the radial lines.

This expenditure, relatively low in comparison with the total cost of the underground system, will give an enormous saving when the system is extended, whilst improving the working very considerably.

625. 144. 1]

ıe maximum length of rails as affected by the range of temperature and the design of the rail joint.

s question was wade the subject of Tech- ical Paper No. 297 (of the Indian Railway oard), the author of which is Mr. A. M. IMS, Officiating Deputy Chief Engineer, orth Western Railway (India).

ome years ago, the Track Standards nmittee had expressed the opinion t it would be desirable to aim at a gth of 60 ft. for rails in the future. ing chiefly to the difficulty of trans- tation, the Railway Board issued or- s (1931) that this matter should nd over.

t was likely, on the other hand, that ls of such length would require spe- l arrangements at the joint in order allow of free expansion under the ect of variations in temperature.

nvestigations into the deformations rails and the actual temperature ran- led Mr. Sims to formulate the follow- conclusions :

On the North Western Railway, in the Punjab plains, an annual range of rail temperatures of 26° F. to 146° F. has been observed; If 60-foot rails are to be used, slight alterations will be required in the existing standard rail joint designs; for instance the diameter of the fish-bolt holes in the web of 115-lb. B.S.S. rails should be increased to 1 1/2 inches. Furthermore the initial stresses which may exist in rails should be recognized, as the sum of these stresses and those resulting from the passage of the locomotive may be above the permissible limit.

* * *

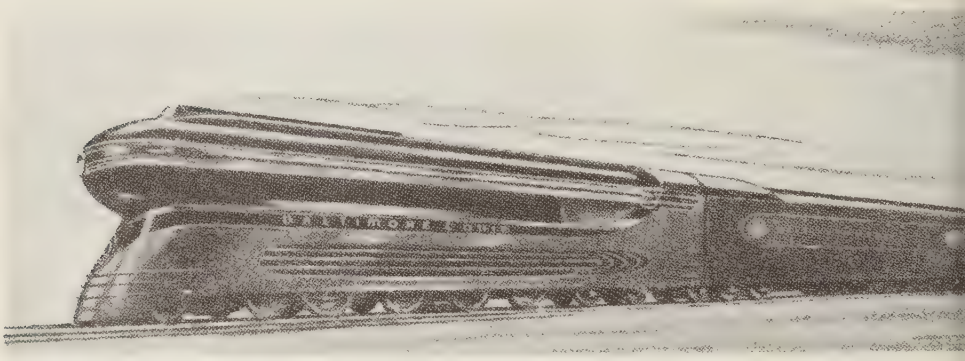
Several tables appended to Mr. Sims's paper show the results of observations made.

R. D.

RECENT DEVELOPMENTS
IN RAILWAY PRACTICE.

[621. 132.8 (.73)]

New 16-cylinder constant-torque locomotive designed by the Baltimore and Ohio Railroad Company.

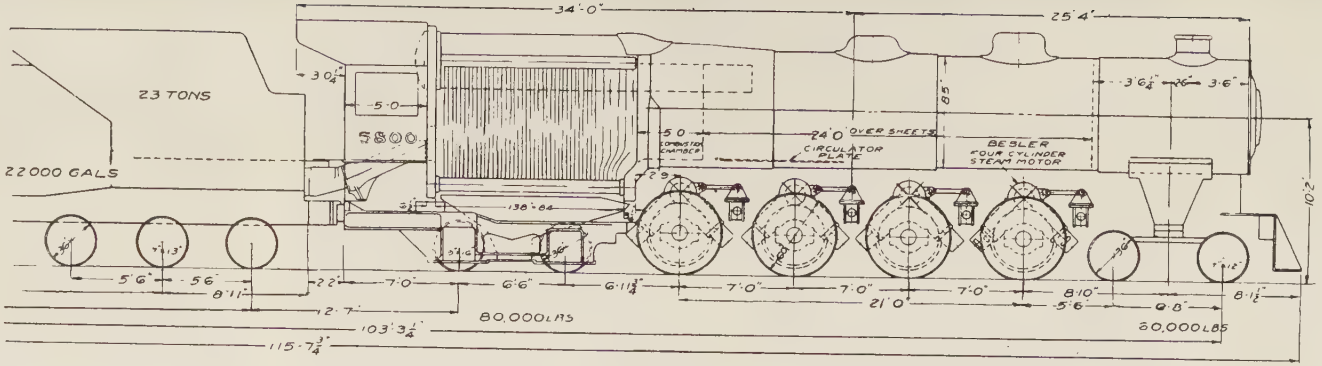


The Baltimore and Ohio Railroad has just completed the design of a powerful new locomotive which is a radical departure from the conventional type, but which nevertheless incorporates fundamental engineering and mechanical principles whose efficiency has been amply proved.

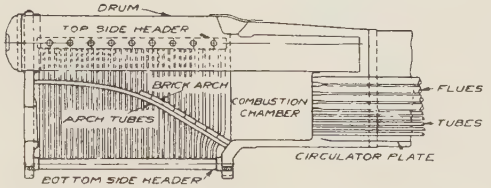
Built with 16 cylinders arranged for *Constant Torque* propulsion, the locomotive will produce a continuous flow of power similar to that of a multi-cylinder automobile — with smooth running and minimum vibration. It is believed that it will develop 5 000 horse-power, and that it will be capable of handling 14 standard Pullman cars at a speed of 100 miles per hour on straight, level track.

On June 3 last, the Baltimore and Ohio put into service the first four-cylinder 4-4-4-4 locomotive of its type ever built. With its front pair of cylinders « pulling » the two forward pairs of drive and its rear pair of cylinders, (under t cab) « pushing » the second two pairs drivers, it has developed tractive eff equal to that of the Baltimore & Ohi biggest mountain type locomotive, 65 0 pounds, and at the same time cut pist thrust and the weight of main and co necting rods approximately in half.

While this four-cylinder locomoti was being built, Daniel Willard, pre dent of the Baltimore & Ohio, fully su scribed to the soundness of its desi and this has since been amply proved daily tests in heavy freight and passe ger service. Yet he stated that he con dered that the ideal steam locomoti would be one with a power unit for ea pair of driving wheels — each unit to of a continuous torque type, direc geared to the axles of the locomoti Now this ideal design has been develop

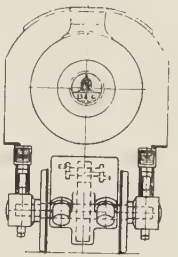


Baltimore & Ohio 16-cylinder constant-torque steam locomotive.



Cut away view of firebox, Emerson water tube type.

Tractive power		72 500 lb.
Factor of adhesion		3.6
Cylinders	Number	16
	Diameter	9 1/2"
	Stroke	7"
Gear ratio		19 to 55
Total horse-power		5 000
Diametral pitch		1.25, Face 10"
Pitch diameter of	gear	44"
	pinion	15.2"
Boiler pressure		350 lb.
Firebox size inside		138" × 84"
Grate area		80.5 sq. ft.
Boiler capacity		115 %
Heating surface	firebox	775 sq. ft.
	tubes and flues	5 025 sq. ft.
	total	5 800 sq. ft.
Superheating surface		1 530 sq. ft.
Total weight	on drivers	260 000 lb.
	of engine	400 000 lb.
	of tender	350 000 lb.



The locomotive has a 4-wheel front truck, four pairs of drivers, a 4-wheel trailer truck, and a tank mounted on two 6-wheel trucks and carrying 23 tons of coal and 22 000 gallons of water.

Counterbalancing eliminated.

Each of its four driving axles will be driven by a Besler steam motor and each motor has 4 cylinders directly geared to its axle, so that there will be a total of 16 cylinders with 32 power impulses for each revolution of the steam motors. No counterbalancing of any kind, and no main and side rods and crank pins, will be required, this new design thus entirely eliminating the hammer blows on tracks that result from counterbalance weights. The absence of main and side rods and other motion work, will also make it possible for the driving wheels, with their independently mounted 4-cylinder steam motors, to accommodate sharper curves than with locomotives of conventional design.

The gears and all other motion parts of the steam motor will operate continuously in a bath of oil forced by a pump to the wearing parts, as is done in the modern automobile. The cut-off position of the valve gear, together with forward and reverse motion, will be automatically regulated from the locomotive cab by means of an electro-pneumatic control.

Total weight of the locomotive will be about 400 000 lb., with 260 000 lb. on the drivers. The starting tractive power will be 72 500 lb., giving a factor of adhesi of 3.6, which is more than ample whe there is constant torque.

Water-tube type boiler.

The boiler will be of the Emerson w ter-tube firebox type with 775 sq. ft. heating surface in the firebox, and a to heating surface of 5 800 sq. ft. It w have a superheating surface of 1 530 ft., will be equipped with feed wa heater, and will have a capacity of 115 The Besler steam motors operate on guaranteed rate of 14 lb. per hor power/hour, so that when the locomoti is developing 5 000 horse-power, the c linders will require 70 000 lb. of wa per hour while the boiler will evapora 80 500 lb. The working pressure of t engine is 350 lb.

The new locomotive will be very fle ible. It will have outside frames a spring rigging; also outside jour boxes, which will be oil lubricated. Ea pair of driving wheels with its attach steam motor can be quickly removed the drop pit for necessary repairs, su as turning of tires, adjustment of drivi boxes, etc.

The locomotive will be streamlined the pattern developed for the Baltimore Ohio two years ago by Otto Kuhler, co sulting engineer of design, and which h been used in an adapted form for t streamlining of the railroad's diesel-el tric locomotives and its New York tra connection motor coaches.

MISCELLANEOUS INFORMATION.

62 (.01 & 621. 43]

1. — Cylinder wear in internal combustion engines. Methods of prevention,

by H. N. BASSETT,
Chief Chemist, Egyptian State Railways.

(*Modern Transport.*)

ne of the heaviest items in the operating s of a motor vehicle is the fuel bill, and saving which can be effected in this ıection is naturally of the utmost impor- e to an operator. The condition of the ne has a great influence on fuel costs, and s mainly on this account that the pro- ı of cylinder wear is now receiving so h attention. Some wear, of course, is in- ıble, but when it reaches a certain point ·ads to waste of fuel and overhaul is re- ed. There are several factors which con- ıte to wear in the cylinders, a major one g the presence of abrasive matter. This reach the cylinders either with the fuel y way of the lubricating oil; in the latter the source is usually the air used for ɔustion. Petrol is free from mineral ash, diesel fuels always contain some, the unt varying from 0.005 % to 0.05 %, g, as a rule, greater the more viscous the The ash is so extremely fine that it es all kinds of ordinary filters, the only which will remove it being a Stream-line r. For this reason it is advisable to put liesel fuel through such a filter after de- y to the storage tanks and before issue ehicles.

ɔrasive matter which circulates in the lu- ıting oil should be removed from the air ıeans of a filter before the air enters the ıders. There is no doubt of the necessity ın air filter in the case of vehicles which to operate over dusty roads. An effi- oil filter will retain the bulk of the ended matter, but periodic changing of oil (say, every 1 500 to 2 000 miles) is ımmended. The oil thus removed can be cleaned by means of a Stream-line filter and used again, though in the case of oil from petrol engines, it is advisable to remove the light fuel hydrocarbons which have reduced the viscosity. Oil from diesel engines does not, of course, suffer such dilution and can be used directly after filtration.

Operating conditions.

The operating conditions also have an important influence on cylinder wear. The use of too rich a mixture in petrol engines leads to the oil film being washed off the walls, as well as to excessive dilution in the crankcase. There is also ample evidence to prove that frequent starting and stopping leads to much more rapid wear than when the engine is allowed to run continuously. Tests have also shown that wear is less when the cylinder walls are kept hot.

This means that the temperature of the cooling water should be kept high, but not allowed to boil, therefore every care should be taken to keep the water spaces free from scale. Such scale, when formed, acts as a heat insulator, so that the wall temperatures rise excessively. In some experiments which were carried out with a motor vehicle engine it was found that « scuffing » (scoring) of the walls by the piston rings began when the temperature of the walls reached 400° F., at which temperature the lubricating oil film began to break down. Such a temperature can be reached easily if the water passages are blocked with scale. Scuffing leads to serious increase in fuel consumption.

So far no conclusion has been reached as

to whether or not corrosion is the major factor in cylinder wear, but there is reason to believe that it is. It would account, for example, for the big difference in the rate of wear of internal combustion engines and high-speed air compressors, for in the latter machines no wear takes place at all worth mentioning over very long periods. It would also explain the fact that wear is much more pronounced on cylinder walls than on piston rings, because the faces of the rings are not exposed to the corrosive effect of the gases resulting from combustion. The corrosion hypothesis to explain wear would also account for the fact that hardness, of itself, does not seem to be the most important property in a liner or cylinder for resisting wear.

Chromium-plating.

A recently-introduced process which is giving goods results is the deposition of a skin of chromium on a specially prepared cast-iron surface. The skin so formed is extremely hard, and at the same time it is particularly resistant to corrosion. The wear under test was found to be a third of that which took place on nitrogen-hardened cylinders. It seems probable, therefore, that the problem of liner wear must be tackled by the provision of liners of specially prepared corrosion-resisting material.

The finish of the bore in the first place has a good deal of influence upon its later life. During the running-in period the irregularities of the bore are smoothed down, and in time a perfectly smooth surface is obtained upon which but little further wear may take place. The particles of iron which are worn off in the period, however, remain in circulation and are abrasive. It is important, therefore, to filter the oil after the first 1 000 hours of use, to remove this abrasive matter. If colloidal graphite is used the wear during running-in is less, and the finish obtained is better. Obviously the better the finish in the first place the sooner the final running skin will be formed, and therefore honing is recommended, and the addition of colloidal graphite to the honing fluid is of great benefit.

The running-in period.

Lubrication is a decidedly important fact in cylinder wear, especially in the early da of the engine's life. For the first thousa miles it is well worth while to use a lub cant containing colloidal graphite, as by doing a smooth film (the so-called « grapho film ») is formed. This skin has a low c efficient of friction, and is also resistant corrosion. Once the skin has been form there is less advantage in using colloidal gr phite.

It is also important always to use oil good quality, even if it is not cleaned a used again. The amount of oil used in p portion to the amount of fuel burnt is small that the additional fuel consumpti and the extra wear which result from t use of inferior oil more than counterbalan the saving in the cost of the lubricant. In rior oils lose their viscosity more readi when heated than do those of better qualit they oxidise more readily, and hence fo more sludge in the crankcase; they tend form heavier carbon deposits, and to ja rings in the grooves (which lead sometim to breakage of rings, and always to inefficie operation because of blow-by of the gases and they have a higher coefficient of fr tion.

Compounded oils.

It is largely a matter of personal pre rence whether the oil used is a straight mi ral oil or is blended with fatty oil or co pound. Excellent results have been and a being obtained with straight mineral oils, b a compounded oil containing fatty oil or fat matter gives better results. One brand proprietary oils now available, besides bei blended with a fatty oil, also contains a ve small quantity of a tin salt, which slows do the oxidation of the oils in use, hence po poning their deterioration. Such oils gi better service than any mineral oil can pos bly give, because of their longer life bef appreciable sludge formation takes place the crankcase. Every endeavour should made to use as little oil as possible. The u

an excessive amount leads to the forma- of heavy carbon deposits which affect running of the engine, and which fre- ntly cause the rings to jam. The use of rge quantity of inferior oil is not an ade- e substitute for a smaller quantity of an of high quality. An inferior oil is dear ny price, and should not be used.

Conclusions.

he effect of the composition of the cylin- block or liners has been mentioned briefly ady. If it is conceded that corrosion is most important factor in wear (as it ears to be) and that abrasion is a less im- ant one, then obviously corrosion resis- e is the property most required. Hard- is also necessary, however, because some sive wear does take place. This was de- strated in some diesel engines in an oil ter, in which the port engine was run on nary boiler fuel, whilst the starboard en- was run on gas oil. The wear in the engine was six times as great as that he starboard engine. Many other instan- could be given of the same kind, showing a distillate fuel free from ash like gas is to be preferred to an ordinary boiler which contains ash.

Plain cast-iron is no longer widely used, either for blocks or for liners, because such very much better results can be obtained with alloy irons. Additions of nickel and chromium give irons with a hard, close-grained structure which are highly wear-resistant, whilst being readily machineable. A cast-iron containing 2.5 % of nickel and 1 % chromium can be heat treated to give an extremely hard surface.

It appears, therefore, that cylinder wear may be due to abrasive matter in the fuel, to corrosion, to lack of quality in the oil, and to a poor finish of the walls in the first place. Wear can be combatted by filtering the fuel before it enters the engine through a Streamline filter : by maintaining the cooling water temperature fairly high (but taking care that the water spaces are free from scale) : by using a high-grade oil and by changing it periodically : by honing the cylinders before use, preferably with the addition of colloidal graphite to the honing fluid : and by running-in with colloidal graphite in the oil. The problem of the composition of the metal of the liners has not yet been solved, but solution appears to be along the lines of provision of a reasonably hard, and also chemically resistant, close-grained cast-iron, and in this connection nickel-chromium irons are useful.

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62 (01]

2. — The wear of wire ropes.

(Engineering.)

ıe problem of deciding when to scrap a ı wire rope has always occasioned a con- rable amount of worry to those respon- for maintenance, and to clarify the mat- a good deal of research work has been ed out in recent years. Thus, the Insti- on of Mechanical Engineers had a Wire es Research Committee in existence from until 1935, in which period five reports issued. These dealt largely with condi- of operation as affected by design, and dered as a main point the subject of fati- from repeated bending. It is also known the subject has been receiving the atten- tion of the Safety in Mines Research Board, for whom investigations have been carried out by Professor S. M. Dixon and Dr. M. A. Hogan, this work, which is still being continued, being in charge of the latter since Professor Dixon's retirement. This investigation has covered the examination of a large number of worn ropes, and the results have been published from time to time either in special papers issued by the Mines Department or in the annual report of the Board. The American Society of Mechanical Engineers also has a special research committee at work on the subject.

In the past, however incomplete our knowledge, some working hypothesis has had to be adopted and there have been many attempts to devise rules which would ensure the removal of a rope before it had reached a dangerous condition, while allowing a reasonable amount of wear. Such a rule is given, for instance, in No. 20 *(c)* of the Docks Regulations, 1934 (1), which reads :

« No wire rope shall be used in hoisting or lowering if in any length of eight diameters the total number of visible broken wires exceeds 10 % of the total number of wires, or the rope shows signs of excessive wear, corrosion, or other defect which, in the opinion of the person who inspects it, renders it unfit for use. »

It will be noted, however, that this regulation only lays down a specific ruling in the case of broken wires and the question of what constitutes excessive wear is left to the examiner.

The reduction in strength of a wire rope depends on the loss of metallic cross-section, provided there is no deterioration by fatigue. To estimate the loss of cross-section it is necessary to obtain the thickness of metal worn off the wires. This cannot be obtained directly from the loss in diameter of the rope because compression of the core and internal wear are also capable of producing a reduction of the same order. If the width of the worn surface could be measured accurately the amount worn away might be deduced from this, but the normal roughening and burring of the edges of the worn surface render this method impracticable. Some years ago Messrs. John A. Roebling's Sons Company came to the conclusion that a better estimate of the amount of metal removed could be obtained by measuring the length of the worn surface of the outer wires in the case of ordinary lay ropes (2). For Lang's lay ropes it was found more convenient to measure the dia nal width across the worn surface of th or more wires, measuring from the end of worn surface on one wire to the beginning the worn surface on the fourth wire. In case of ordinary lay the length increases w increase in the amount of wear, whereas the measurement chosen for Lang's lay it creases. Nomographs were devised fr which, if the amount of wear on the wi and the number of broken wires were kno the strength of a worn wire rope could determined. These charts were based on examination and tests of a large number worn wire ropes, but as the relation betwe the lengths measured depends on the leng of lay, they must clearly apply in the ma to ropes having lays resembling the Roebli standards. The complete chart consists two parts, the first having a nomograph which the three vertical scales are rope d meter, worn length, and percentage of w diameter remaining. The second nomogra scales are percentage of wire diameter rema ing, percentage of area of rope diameter tact, and number of broken wires in wo part. The first is used to give the percenta of wire diameter remaining, and this is tra ferred to the second nomograph to determi in conjunction with the number of brok wires, the percentage of rope area intact. a typical case, a 1-inch diameter rope showi a worn length of 0.54 inch gave 70 % w diameter remaining. With no broken wi this gave a rope area remaining of 80 Similar charts were prepared for six ty of round-strand rope in ordinary and Lan lay. Where the broken wires are not u formly distributed throughout the strands correction has to be made which may red the effective area by as much as 10 %.

The application of these diagrams has b recently investigated in a series of tests 229 specimens from 79 worn ropes, which w made at the United States Bureau of St dards (3) in co-operation with the Spe

(1) The Docks Regulations, 1934, *S. R. & O.*, 1934, No. 279.

(2) « Re-Roping Charts », *Wire Engineering*, 1931, June-July; « Stresses in Shaft Hoist Ropes », *ibid.*, 1932, February-March; « Calculating Remaining Strength in Lang's Lay Hoisting Ropes », *ibid.*, 1932, July.

(3) W. H. Fulweiler, A. H. Stang and L. Sweetman, « Inspection and Tensile Tests Some Worn Wire Ropes ». *Journal of U. Bureau of Standards*, vol. 17, page 401, 19

arch Committee on Wire Rope, mentioned e, of the American Society of Mechanical neers. The specimens ranged in diameter 1/4 inch to 3 1/4 inches and 18 diffe- types of construction were represented, f round strand. They hav been used on cranes, dredges, mine haulages, and on ers in vertical shafts. The specimens examined, the number of wires broken e worst lay was counted, and the diame- nd length of the worn surfaces measured. this information the breaking strength computed with the aid of the charts. The mens were tested in tension, and the l breaking load was somewhat greater the value computed from the charts. in the case of 19 out of 109 specimens the breaking strength less than the com- l value. The most serious discrepancies rred in ropes which had broken wires si- d between the strands and not on the surface. These « valley » breaks may been due to internal wear or to fatigue, er of which sources of deterioration are into account in the charts. Corrosion another cause of discrepancy. As the s were only intended to apply to ropes rgoing external wear, these discrepancies ot affect the general result of the investi- n, which was to confirm the accuracy of harts.

is to be noted that in these experiments ame method of measuring the strength, tic tensile test, was employed as in Roe- s tests, on which the charts were based. ded a rope does not contain any wires ed or broken by fatigue, there can be objection to the use of a static tensile for determining the strength. The case tirely different, however, if broken or ed wires are present. In a static tensile very considerable friction is developed en the wires and strands and a broken will take up its load again in a very distance. Consequently, only those frac- which are situated within a couple of rope lays of the final break are effective in reducing the breaking strength. A wire rope in service is stressed while bending over pulleys or drums, and the wires are in relative motion, so that the friction between them is much reduced. This allows the broken wires over a considerable length of rope to form part of the fracture, and the tensile strength may be much less than in a static test. For example, in some laboratory tests carried out at the German Experimental Mine (4) it was found that the load required to break a worn rope while moving over a pulley was only about a third of the tensile strength developed in a static test by an identical piece of rope with the same number of broken wires. Although this may have been an unusually low result, it is of considerable importance as illustrating the need for caution in interpreting the results of static tensile tests on ropes containing broken wires.

Another reason for caution in dealing with ropes containing broken wires is that the breakages have been produced by the action of repeated stressing, which has also affected the remaining wires and still continues to do so. Hence, if, say, 10 wires out of 54 have failed in fatigue, there is no reason why any or all of the remaining wires should not fail within a relatively short time. Actually fatigue deterioration tends to proceed at an accelerating pace because the failure of some of the wires causes the remainder to be overloaded.

In so far as the Roebling charts can be applied to ropes suffering external wear, but free from corrosion, fatigue and internal deterioration, the results can clearly be trustworthy, and similar charts for the types of rope commonly used in Great Britain, if prepared, would probably fulfil quite a useful purpose.

(4) H. HERBST, « Zur Bewertung von Drahtbrüchen für den Sicherheit von Förderseilen », *Bergbau*, 1934, 125.

NEW BOOKS AND PUBLICATIONS.

[656]

TAJANI (F.). — **Concorrenza e monopolio nell' esercizio dei trasporti. La lotta fra ferrovia ed automobile** (*Competition and monopoly in transport matters. The struggle between the railway and the road motor vehicle*). — A pamphlet ($9\frac{3}{4} \times 8\frac{1}{4}$ inches) of 58 pages, illustrated. — 1936, Libreria Editrice Politecnica, Cesare Tamburini fu Camillo, Milan, Via G. Pascoli 55—Piazza Cavour, 2.

In the opinion of the author, competition between road and rail transport is one of the most important factors in this century's economics. Particular attention should be devoted to it owing to its effect on the financial position of the railways and the repercussions thereof on the general economics of the country in which it takes place.

In his brief study of 56 pages, Sr. Tajani gives a brief and substantial review of the question. Obviously, he has the particular circumstances of his own country mainly in view, but the considerations developed are in the main relative to phenomena obeying the laws of political economy, and therefore are of general application.

The author has given the discussion a scientific basis, without, however, carrying the theory of the question too far. For this purpose, he uses the curve of requirements under a monopoly, obtained by plotting the traffic as abscissae corresponding to the charges plotted as ordinates, the charges being taken as being sufficiently diversified to cover the actual needs and possible requirements of the public. The area between the curve and the horizontal datum line represents the possible receipts. That lying above the partial cost price represents the amount that can be allocated to the fixed charges. By this simple graphical method the author is unabled to explain the results in concrete cases of transport competition and to predict what would occur under similar conditions.

In the first chapters, which form the theoretical part, the author, by mea of the said monopoly curve, shows t essential differences between compe tive undertakings and those enjoying more or less marked monopoly. At t same time, he shows how a wider p tronage can be obtained by a diversifi ation of the rates (according to kinds products) and by a differentiation the rates (according to the importan of the traffic).

Having defined the various cost pric and analysed the expenditure, the auth shows how the use made of the trai can affect the cost per passenger-kilom tre and per tonne-kilometre. The noti of the partial cost price shows the val of bulk traffic at low rates and also t damage done by competition betwe lines covering the same services.

In the subsequent chapters the abo ideas are applied to the various class of competition that may occur, betwe railways, between rail and road, a other forms of transport.

The author has no difficulty in showi that competition between methods transport of the same kind in the end not in the public interests as it imper the existence of the transport underta ings themselves.

As regards competition between r and road, the railway, if it is to reta its traffic, must lower its rates bel the monopoly values, i. e. it must ap to the higher classes of goods the ra for the low classes, which reduces t gross receipts and makes it impossible distribute the fixed charges rationa

e result is the more noticeable that the ed charges of the railway are higher n those of road transport. When the er reduces its charges to nearly its ss costs, the railway is forced to give a much greater proportion of the rage or gross cost.

The proposed solutions differ for passger and for goods transport. In the mer case Sr. Tajani recommends the nting of concessions. Free competon, even when restricted to the road rriers, can only lead to their ruin or to reements between them. It is better to ide up the traffic authoritatively, i. e. means of concessions. By this means continuity of the public services can assured. Twenty years' experience Italy shows that this method develops ffic in areas with neither railways nor mways. The proposed organisation ovides for the refusal of concessions ich would harm existing railways, ilst granting those which could bring ffic to it and avoid heavy construcnal charges unjustified by the amount traffic to be dealt with.

As regards goods transport, the author otes figures for the cost of carriage by ht and heavy lorries. These show t when only the partial cost is consired, the railway under competitive nditions will be obliged to abandon e monopoly rates for the high-rated ods, as the road carriers are competg with one another in a ruinous fashn. The consequences, however, are ich more serious for the railways owg to their higher fixed charges. The ss in Italy reaches 900 million lires r annum.

The author does not suggest the conssion system as a remedy. He also rets the idea of collaboration as being dly defined and only meaning an reement to apportion the traffic. Now, is is the natural outcome of competion, i. e., a divided monopoly. Moreer, it appears that the agreement would imposed in favour of the railway, which is the competitor suffering the greater loss.

He also considers the setting up of subsidiary organisations as inadequate; such organisations cannot do away with the cause of the harm done. Nor should the efficacy of technical methods, such as containers, road-rail wagons, etc... be exaggerated. Against this, the provision of private sidings should be made easier.

The solution is to be found in the setting up of a co-ordinated and carefully supervised State monopoly. The system tested in Germany may be suggested; it resembles the Post Office monopoly.

As is known, the Italian method is to tax road transport, the proceeds being paid to the Treasury to reduce the railway deficit (the tax is 12 centisimi per tonne-kilometre on transport for third parties and 8 centisimi for private traffic). The road transport competitive rates can be raised moreover by the State. This method must be considered as a logical application of the monopoly system.

Sr. Tajani, however, suggests a corrective thereto. He sees the solution in the grant of concessions for carrying goods over routes not in competition with the railways. The concession holder would be required to fix maximum rates (with a goods classification), but could lower the rates to meet the competition from private transport which bears only low taxes. The concession holder also would be under the obligation to carry, or at least possess a minimum of equipment. The goods carried over other routes would only pay the present rates. The proposed system appears better than a transport tax over any route, as this may prevent goods of low value being carried.

After reviewing the other forms of competitive transport, the author brings out the public service character of the railway which has to carry all traffic offered and is prevented from granting agreed charges. He demonstrates the essential part played by the railway

in the national structure, and refutes the argument that the automobile represents progress before which the railway must give way and finally disappear. The road motor vehicle may make a good impression, as it forms a complement to existing methods, but it would be a mistake to hand over to it the essential p of the work. This is not saying tha has not its own special field of acti it has rendered services in areas w light traffic, where it has replaced ra ways and tramways.

E. M

[656 (493]

CASTIAU (Marcel), General Secretary, Ministry of Transport (Belgium). — **Le préser et l'avenir des transports en Belgique** (*The present and future of transport in Belgium*) — Abstracted from the *Revue Economique Internationale.* — A pamphlet (9¾×6¼ inches of 36 pages. — 1936, Brussels : Goemare, publisher, 21, rue de la Limite.

This note completes the book « Les transports en Belgique et leur coordination » (Transport in Belgium and its coordination) which was reviewed in the *Bulletin* for October 1936. It goes back to the question of the steps already taken to improve the transport industry in Belgium and those which should be taken in the future.

After reminding his readers that one of the causes of the present crisis is the excessive development of the means of transport as compared with the volume of traffic to be carried and insisting on the special position of the railway which entitles it to special consideration, the author gives the legal and administrative measures taken to regulate road transport. The last step taken concerns goods traffic. As in many other European countries, a system of licences has been instituted. In the author's opinion, these measures should be completed by a revision of the railway rating system on the one hand, and on the other by stricter regulations on the circulation private road motor vehicles.

The intervention of the public aut rities has been criticised by certain c riers. As regards inland navigation, Castiau points out that its troubles due rather to its own competition th that from the railway, and he quo again some figures given in his previ book, as regards the actual cost of tra port by water, and the distribution the charges it has to bear.

As regards the *future of the railw* the author formulates various consid ations which go to prove that it is possible to foresee the road taking place of the railway, both as rega passengers and goods, *for many years come* (a reservation which in our o nion is disproved by the arguments forward). As regards canals, it wo appear to be a mistake to spend m on enlarging them or building new o

E. M

[621.13 (.4) & 621.43 (.4)]

LIPETZ (A. I.), Chief Consulting Engineer, in charge of Research, American Locomoti Company, Schenectady, N. Y. — **Recent Developments in European Railroad Moti Power.** — A pamphlet (8¾ × 12 inches) of 15 pages, with 17 figures, reprinted fro *The Engineering Journal,* February 1937 issue. Montreal (Quebec), The Montre Locomotive Works Limited.

This pamphlet reproduces a very interesting lecture given by Mr. Lipetz, Chief Consulting Engineer of the American Locomotive Company, on the re improvements made in Europe to st locomotives, diesel locomotives and

railcars in order to get the ever higher eds required under the new operat- conditions. So as to be able to com- e the performances of these three ds of equipment. Mr. Lipetz makes of the « specific power factor », i. e. ratio of the power at the rail as de- nined on test to the weight of the ım locomotive with half-loaded tender ɔ the weight of the diesel locomotive rain with full tanks as the case may he gives some very interesting com- ative tables in connection with this ter.

The lecture reviews the results obtain- in France by the rebuilding of certain es of locomotives on the principles laid down by Mr. CHAPELON, by the adoption of new designs of exhaust, and the use of streamlining; the characteristics of new types of locomotives being built or designed in France are also given, and new features in steam locomotive design in England and Germany, and the pamphlet ends with a brief note on the rapid development of the diesel locomotive and in particular of the diesel railcar, especially in France and Germany.

Under these conditions, this review of the evolution of motive power in Europe, as seen by a specialist American Engineer, is of particular interest.

A. C.

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385. (02]

LACE (Pierre), former pupil of the Polytechnical School, Engineer, Head of the Test Department of the Central Railway Equipment Designing Office (O.C.E.M.). — **Chemins de fer — Agenda Dunod** (Railways — Dunod Pocket Book), 1937 (56th edition). — One volume (4 × 6 inches) of CXLIV + 407 pages, with 98 figures. — Dunod, publisher, 92, rue Bonaparte, Paris (6e). — Price, bound in imitation leather : 20 French francs.

Every year railway technicians find the Agenda DUNOD, « Railways », y important and up-to-date informa- ı on the *permanent way* (estimation the probable traffic, cost of construc- ı and operation, administrative for- lities, design of the track, feeder sta- ıs, traffic currents, etc...), on *traction* ain resistance, power of the locomo- es, loads, steam locomotives, railcars, ctric traction and ferryboats); on *ling stock* (different designs of pas- ger and goods stock, brakes, lighting l heating, etc...); and finally on the *ration* (traffic, safety devices, rates, receipts and expenditure, taxes, statistical information).

The 1937 edition includes a table giving the length of lines built to the different gauges, and the following new information :

Wooden, metal, and reinforced concrete sleepers, and composite (wood and steel) sleepers.

Notes on the calculation of the traction resistance.

28 graphs giving information of various kinds about steam locomotives.

Ferryboats.

Note on viscosity.

1934 signal code.

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621. 355]

ROWN (H. G.), A. M. I. E. E. — **The Lead Storage Battery.** — A volume (5 1/2 × 8 3/4 inches) of 202 pages with 101 figures and many diagrams. — The Locomotive Publishing Company, Ltd., 3, Amen Corner, London E.C. 4. (Price : 5 sh.)

The third edition of Mr. Brown's book lead storage batteries has just been ued. This book deals with the electrical characteristics of the accumulator; the structure and formation of the plates; the conditions applying to the use of sta-

tionary batteries; the auxiliary apparatus : boosters, regulator switches, cut-outs, etc...; the care, treatment and repair of cells; battery testing, and in particular the cadmium tests. Part of the book is devoted to portable cells and their use on motor vehicles, shunting locomotives, trucks, etc...

The book ends with diagrams of stand-by lighting installations fed by batteries and gives as an appendix a report on ionic theory and instructions for test the water and acid for the electrol The lead storage battery is widely u in railway plant and rolling stock, this fully documented handbook supply the technician with the pract information he may require.

A. (

[621. 392]

BONDY (O.), Dipl.-Ing., M. I. Struct. E., Consulting Engineer, London. — **Modern Rai way Welding Practice.** — A volume (5 1/2 × 8 1/2 inches) of 128 pages, with mar figures. — 1937, London, *The Railway Gazette,* 33, Tothill Street, Westminster, S.W. (Price : 5 sh. net.)

In this volume, published by *The Railway Gazette,* Mr. Bondy has collected together a series of noteworthy articles published in this Journal and *The Railway Engineer* from 1934 onwards, on the most important applications of welding in the various fields of railway working, more particularly in connection with British and especially German practice.

After a brief review of the progress achieved during the last years in the applications under consideration, the author devotes fully documented chapters to the construction by welding, particularly in Germany, of wagons and coaches, and the use of welding processes in the construction of locomotives and railcars; in this connection he gives details about checking the welds by means of X-rays.

In a special chapter, the author co ments upon, and compares, the regu tions and specifications on welding force in England and Germany in pa cular. Another part of the book cludes several chapters on the meth of building and strengthening railv bridges by electric welding, the c struction of shelters on passenger stat platforms, and the most recent progr in rail welding.

Consequently this book, edited w great care, and profusely illustrat gives in a concise form very valua information on the most recent progr in welding technique, in the constr tion of railway permanent way, bu ings and rolling stock.

A. (

[62 (01 & 625 .145]

HUNGARIAN ASSOCIATION FOR TESTING MATERIALS. — 3rd **International Day Rails** (Budapest 8-12 September, 1935). One volume (11 1/2 × 8 1/4 inches) or 262 pag with many photos and drawings. — 1936, Hungarian Association for Testing Materia Budapest XI, Müegyetem. (Price : 20 Rm.)

The questions on the agenda for this Rail Congress can be grouped under the following headings :

I. General questions.
II. Wear.
III. Brittleness — internal stresses — age
IV. Experimental results in service.
V. Design of points and crossings mad rails.
VI. Welding.

he many reports presented to the gress are reproduced in this volume. shown by the summary, questions of sent-day importance were dealt with throughhly competent reporters.

full list of the reports cannot be gi-, but the following are mentioned reference :

os & Eichinger : Results of laborato- and service tests on ordinary rails arious qualities, or heat-treated.

ühnel : Endeavours to improve rail ls in Germany.

örber (Kaiser Wilhelm Institut) and *ovar* (Thyssen) : Contribution to the estigation into the alterations in the tic properties of newly rolled rails ording to the time elapsed after leav- the rolls.

ey : Results of tests of rails in ser- on the Royal Hungarian State Rail- s.

eodorescu : Inspection of rails and lication of the results in practice.

allik and *Hoensch :* Effect of straigh- ing on the elastic properties of rail l.

chrönrock (Krupp) : Investigation the reciprocal wear effects between tyre and the rail.

zeless : Rail wear tests by the Spindel hod.

raki and *Saito :* Further investiga- ns into rail and tyre wear, made by Japanese Government Railways.

chulz and *Gerold :* Effect of internal sses on the life of rails.

Munro : A method of revealing intern- al defects in rails (Sperry equipment).

Bartel : Contribution to the investig- ation into the resilience of rail steel.

Walzel : Investigations into the life of points and crossings.

Meucci : Methods of preventing break- ages and excessive wear of rails in points and crossings.

Huber : Investigation into the stability of jointless track.

Csillέry and *Péter :* The weldability by the electric arc process of different rail steels.

Melhardt : Autogenous welding of rail joints (Böhler X joints).

Dobrowolski : Building up worn rails by oxy-accetylene welding when repair- ing the track.

Keel : Autogenous welding of rail joints and building up of worn rail ends.

Mercier : Use of welding for securing electric connections on railway lines.

Kazinczy : Mechanical tests of welded rail joints.

Forcella : Paper on a special method of welding rail joints by the electric arc process.

During the Congress these reports were discussed and information given by well-known specialists. The volume forms an *up-to-date* addition to our tech- nical knowledge on rails and will be consulted with advantage not only by permanent way engineers but also by all engineers interested in steel testing.

R. D.

662]

technique des industries du pétrole (*The Technique of the Oil Industry*) (*Science et Industrie,* a Monthly Review; special issue). — One volume (10×12 inches) of 208 pages, profusely illustrated. — Paris, 29, rue De Berri.

he oil industry covers a particularly t field from its extraction to its con- ıption under the most widely differ- forms; new by-products giving rise to new utilisations are frequently being discovered. To celebrate the Second World Oil Congress, held in Paris in 1937, the Review *Science et Industrie*

has published a special number with a great many illustrations, exclusively devoted to this important industry.

After having recalled the object and work of the firms engaged in the oil industry in France, and in particular the « Association Française des Techniciens du Pétrole » (French Association of Oil Specialists), the « Office National des Combustibles liquides » (National Liquid Fuels Office), and, as far as instruction is concerned, the « Ecole Nationale supérieure du Pétrole et des Combustibles liquides » (National High School of Oil and Liquid Fuels) of Strasbourg, the book reviews the programme of the Second World Oil Congress which consists of five groups; geology and boring; physical chemistry and refining; plant and construction; use of liquid fuels; economics and statistics.

A series of well documented articles are then devoted to oil prospecting and boring technics; very important articles deal with the present position of the hydrogenation problem in France a abroad, with the adaptation of Fre refineries for the production of mod motor fuels, with petroleum as a raw m terial for the chemical industry. We v also mention the interesting Notes on position of French oil engine build as regards fuel, on motor fuels wit very high octane content, on the ma facture of propane and butane, on blending of mineral oils, on the pl used in the oil industry, on the devel ment of French oil ports, on the stori of hydrocarbons in France, on the u of paraffin and on questions of saf and hygiene in the oil industry.

This brief enumeration of the artic contained in this publication shows wide interest for the oil technician, w will find therein information as co plete as it is varied, on questions wh are in the forefront technically spe ing.

A. C

[625. 61 (01]

PAULY (J.), Sous-directeur, Belgian Ministry of Transport, Secretary of the Advisor Committee on Tariffs. — **Etude sur les chemins de fer vicinaux, leur co-ordinatio aux grand réseaux** (*Note on light railways and their co-ordination with the main-lin railways*). — A pamphlet ($7\frac{3}{4} \times 6\frac{1}{4}$ inches), of 52 pages. — 1936, Editions du Comit Central Industriel, 33, rue Ducale, Brussels. (Price : 7 francs.)

This pamphlet deals with competition between standard and narrow-gauge railways, made possible by the differences in the rate systems, and the advisibility of remedying this state of affairs, which stultifies all the efforts made to obtain co-ordination of main-line and light railways, required by the public interests.

The auhor does not minimise the co plexity of the problem with which he dealing, an immediate solution of wh would certainly be impossible. But brings out the benefits that would crue from a close collaboration betw the two railway systems.